PHILOSOPHICAL

TRANSACTIONS

OF THE

ROYAL SOCIETY

OF

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PART II.

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MDCCCXLIX.

Adjudication of the Medals of the Royal Society for the year 1849 by the President and Council.

The Copley Medal to Sir Roderick Impey Murchison, F.R.S., "for the eminent services he has rendered to geological science during many years of active observation in several parts of Europe; and especially for the establishment of that classification of the older palæozoic deposits, designated the Silurian System, as set forth in the two works entitled 'The Silurian System founded on Geological researches in England,' and 'The Geology of Russia in Europe, and the Ural Mountains.'"

The Royal Medal in the department of Physics, to Lieut.-Col. Edward Sabine, Foreign Secretary R.S., for his "Contributions to Terrestrial Magnetism," published in the Philosophical Transactions for 1846, Parts VII. and VIII., and his Memoir "On the Diurnal Variation of the Magnetic Declination at St. Helena," Part I., published in the Philosophical Transactions for 1847.

The Royal Medal in the department of Geology, to Gideon Algernon Mantell, Esq., LL.D., F.R.S., for his paper "On the Iguanodon," published in the Philosophical Transactions for 1848, being a continuation of a series of papers by him on the same fossil animal, by which he has rendered eminent services to geology.

The Bakerian Lecture for 1849 was delivered by Michael Faraday, Esq., F.R.S., and entitled "Experimental Researches in Electricity.—Twenty-second Series. On the crystalline polarity of bismuth and other bodies, and on its relation to the magnetic form of force."

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PHILOSOPHICAL TRANSACTIONS.

XII. *Contributions to Terrestrial Magnetism.—No. IX.*

By Lieut.-Colonel EDWARD SABINE, *R.A., For. Sec. R.S.*

Received May 24,—Read June 21, 1849.

Containing a Map of the Magnetic Declination for 1840 *in the Atlantic Ocean between the parallels of* 60° *North and* 60° *South Latitude.*

IN compliance with repeated representations from the Hydrographer of the Admiralty, that a correct map of the magnetic Declination over the Atlantic Ocean corresponding to the present epoch was most urgently required for the purposes of navigation, I have deemed it proper,—partly on account of the importance of the object itself, and partly in acknowledgement of the claim which the practical wants of those who traverse the seas have on that physical science which they so much contribute to advance,—to suspend the progress of the publication of the observations made at the colonial magnetical and meteorological observatories, until in compliance with the wishes of the Admiralty a Declination map of the Atlantic has been completed. I have endeavoured at the same time so to conduct and arrange the preliminary investigation, that it may form a fitting part of the magnetic survey of the globe, which is designed to be comprehended in the series of Magnetic Contributions, of which the first eight numbers have been honoured with a place in the Philosophical Transactions.

The limits which have been taken for the map, in respect to latitude, are the parallels of 60° north and 60° south. The number of distinct determinations within those limits, either at sea or on adjacent coasts or islands, which have been reduced and coordinated, amounts to 1480. Each determination is, in the majority of cases, a mean result of several distinct and independent observations. They are all comprised between the beginning of 1828 and the end of 1848; the commencement of 1840 being taken as the epoch of the map; and each determination being reduced to that epoch by the rate of secular change derived by comparison with the map of

the Declination in 1787, published by M. Hansteen in his great work, Magnetismus der Erde, and republished by myself in this country in the Reports of the British Association for the Advancement of Science for 1834. Of the determinations made at sea, all have been corrected for the effect of the ship's iron when observations on which the corrections must depend have been provided. I have discussed those corrections in more detail and at greater length than I might otherwise have done, on account of the practical importance attaching to this part of the subject since the introduction of steam navigation and the increased employment of iron in the construction and equipment of vessels; and in the hope and belief that the discussion may be found to have a practical as well as a theoretical value.

The 1480 determinations reduced and corrected for epoch are arranged in a general Table in Zones, each zone including 10° of latitude; the determinations comprised in each zone are arranged in the order of their longitudes, commencing always with the most westerly: they are all likewise inserted in the map, where they are expressed in degrees and decimals of a degree. For the purpose of drawing the lines of declination in general conformity with the determinations, the latter have been arranged in groups, each group having its mean geographical position at or near the point of intersection of every fifth meridian and parallel, (as far as the observations would permit,) counting from the parallel of 0°, and the meridian of 280°; and in the more frequented parts, and where consequently the number of determinations was greatest, at or near the points of intersection of parallels and meridians distant only $2\frac{1}{2}$ degrees from each other. Each group contains all the determinations comprised within equal distances of latitude and equal distances of longitude on either side of the point of intersection; the distances being so taken that the number of determinations constituting a group should be generally from ten to twenty.

If the mean geographical position corresponding to the determinations in a group differed more than a few minutes from the latitude or longitude of the desired point of intersection, one or two determinations adjacent to, but beyond the limit, were taken into the group, or one or two pairs of determinations within the limits were combined and their mean taken instead of the separate results. This was done for the purpose of diminishing the amount of the correction to be applied to the mean declination of the group, to reduce it to the corresponding value of the declination at the point of intersection itself. The factors employed in making that reduction were derived from the map itself. The values of the declination thus obtained at the intersection of every fifth degree of latitude and longitude (as far as the determinations permitted), and at the intersection of every $2\frac{1}{2}$ degrees in the more frequented quarters, have been regarded as *elements* of the declination lines; and these lines have been drawn in accordance with the elements with only such slight deviations as were indispensable to preserve an interconformity between the lines, where it was evident that the determinations themselves were slightly discordant. The values of the Declination at the points of intersection obtained by the process of grouping are

collected in Table VIII., and are also exhibited in the Map in larger and more conspicuous figures than those which represent the determinations from which they are severally derived. The map thus contains, first, the original determinations reduced to the mean epoch; secondly, the elements, or mean values for the points of intersection, derived from the determinations; and thirdly, the lines themselves derived from the elements, so that the degree of accordance of the elements and of the lines with the sources from whence they are derived may be everywhere judged of by inspection.

The determinations employed in this Memoir have been obtained from the following sources:—

(A.) *Sea observations uncorrected for the effects of the Ship's Iron.*

1. Observations made in the corvette Krotkoi by Dr. Adolph Erman in her homeward voyage from Cape Horn to Portsmouth in 1830; extracted from Erman's Reise um die Erde.

2. Observations made on board the Beagle, Captain Robert FitzRoy, on her outward passage from England to South America in 1831 and 1832, and whilst on the South American station, east of Cape Horn, in 1833 and 1834; and on her homeward passage in 1836 from the Cape of Good Hope to the British Channel; extracted from the published account of the voyage.

3. Observations made on board the corvette La Bonite, Captain Vaillant, on her outward passage from Toulon round Cape Horn in 1836, and on her homeward passage in 1837 from the Cape of Good Hope to Brest; extracted from the published account of the voyage.

4. Observations made on board the frigate La Venus, Captain (since Admiral) Du Petit-Thouars, in her outward passage from France round Cape Horn in 1837, and in her homeward passage in 1839 from the Cape of Good Hope to Brest; extracted from the published account of the voyage.

5. Observations made by Captain (since Admiral) Berard, on board the brig Le Voltigeur in a voyage in 1838 from Toulon to Vera Cruz, and from thence by New York to Brest; and on board the corvette Le Rhin, on her outward passage from Toulon to the Cape of Good Hope in 1842, and in her homeward passage from Cape Horn by St. Helena to Toulon in 1846; from a MS. obligingly communicated to me by Captain Duperrey, Membre de l'Institut.

6. Observations made on board La Prevoyante by Captain Jehenne, on a passage from the Cape of Good Hope by St. Helena to Cayenne in 1842; extracted from the Annales Maritimes et Coloniales for 1843.

7. Observations made in H.M.S. Curaçoa, Captain Sir Thomas Sabine Pasley, Bart., whilst on the South American station in 1843 and 1844; MSS.

(B.) *Sea observations corrected for the effects of the Ship's Iron.*

8. Observations made on board H.M.S. Erebus, Captain Sir James Clark Ross, in her outward passage from England to St. Helena and the Cape of Good Hope in 1839 and 1840; MSS.

9. Observations made on board H.M.S. Thunder, Captain Edward Barnett, in a passage from the Bahama Islands to the British Channel in 1841; MSS.

10. Observations made on board H.M. Ships Erebus and Terror, Captains Sir James Clark Ross and F. R. M. Crozier, in the (Antarctic) summer of 1842–1843, between Cape Horn and the Cape of Good Hope; MSS.

11. Observations made on board the Prince Regent transport, by Captain John Henry Lefroy, R.A., in a passage from England to Quebec in 1842; MSS.

12. Observations made in H.M. hired bark Pagoda, by Lieut. (since Commander) T. E. L. Moore, R.N., and Lieut. (since Captain) Henry Clerk, R.A., in a voyage from the Cape of Good Hope to the Antarctic Circle in 1845; extracted from the Philosophical Transactions for 1847.

13. Observations made on board H.M.S. Philomel, Captain Bartholomew J. Sulivan, in a passage from Monte Video to the British Channel in 1846; MSS.

14. Observations made on board the Hudson's Bay Company ship Prince Albert, by Lieut. (since Commander) T. E. L. Moore, in a voyage from England to Moose Fort in Hudson's Bay and back, in 1846; MSS.

15. Observations made on board H.M.S. Rattlesnake, Captain Owen Stanley, in her outward passage from the British Channel to the Cape of Good Hope in 1846 and 1847; MSS.

(C.) *Land observations on the coasts and islands of the Atlantic.*

16. Observations at several points of the South American coast and of the Falkland Islands in 1832, 1833 and 1834, by Captain Robert FitzRoy, R.N.; extracted from the Voyage of the Beagle.

17. Observations at several points of the Falkland Islands and on the South American coast and its vicinity, between 1843 and 1846, by Captain Bartholomew J. Sulivan, R.N.; MSS.

18. Observations during the voyage of the Chanticleer, between 1828 and 1831 at several stations on the coast of the Atlantic, by Captain Henry Foster and Captain Horatio Austin, R.N.; MSS.

19. Observations at various points of the coasts adjacent to the Gulf and River St. Lawrence in the years 1828 to 1848, by Captain H. W. Bayfield, R.N.; MSS.

20. Observations on several points of the Feroe and Shetland Islands and of the Hebrides in 1831, and on the West Coast of Africa in 1836 and 1838, and in the Western Islands in 1843 and 1844, by Captain A. Vidal, R.N.; MSS.

21. Observations made at several stations on the islands and coasts of the Atlantic and Caribbean Sea, from 1837 to 1840, by Captain A. Milne, R.N.

22. Observations at several stations in Guiana in 1842 and 1843, by Sir Robert Schomburgk, employed as Boundary Commissioner; MSS.

23. Observations at several stations in the vicinity of the River St. Lawrence in 1842, by Captain J. H. Lefroy, R.A.; MSS.

24. Observations at several stations in the British Islands in 1838, by Captain Sir James Clark Ross, R.N.; MSS.

25. Observations (with a transportable Declinometer) at stations on the North Coast of Scotland, by Commander H. C. Otter, R.N.; MSS.

26. Observations at several points of the coast of Western Africa in 1845 and 1846, by Captain H. M. Denham, R.N.; MSS.

27. Observations at several stations on the coast of the United States of America in the years 1844 to 1846, in the progress of the United States Coast Survey; extracted from the published Charts of the Survey.

28. Observations (with a transportable Declinometer) in 1848 at stations in the Gulf of St. Lawrence, by Dr. Kelly, R.N.; MSS.

29. Declinations determined at the observatories of Algiers, Brussels, Cape of Good Hope, Christiania, Dublin, Greenwich, Makerstoun, Paris, St. Helena, and Toronto in Canada; extracted from official sources: and at Rio Janeiro by Herr von Helmreicher in 1845 with a transportable Magnetometer; MSS.

30. Declinations observed by Lieut.-Colonel Graham of the United States Topographical Engineers, and by other officers of that corps, and surveyors employed under his direction in the Commission for determining the boundary between the United States and the British Possessions in North America. I am indebted to the liberality and kindness of Lieut.-Colonel Graham for the communication of the manuscript of these valuable observations, which connect the determinations of Captains Bayfield, R.N., and Lefroy, R.A. in Canada, with those of the United States Coast Survey in New York and the more southern states.

Correction of the observations in Schedule (B.) *for the effects of the Ship's Iron.*

Observations in H.M.S. Erebus on her passage from England to St. Helena and the Cape of Good Hope.

When commenting in the Fifth Number of the Magnetic Contributions upon a portion of the magnetic observations of the two first years of Sir James Ross's Antarctic Expedition, which were all that at that time had reached England, I remarked that their examination had led me to the opinion, that the disturbances of the compass in the Erebus and Terror exhibited a character distinct from any which had been previously recognised, either in theoretical discussions or in practical applications. In all the investigations with which I was acquainted, in which the disturbing influence of a ship's magnetism upon her compass had been considered, and in all the remedies which had been suggested, either by the employment of counteracting forces, or by corrections to be applied to the indications of a compass where no such

artificial counteractions were employed, the magnetism of the ship had been regarded either as wholly induced by the magnetic action of the earth and as varying simultaneously with variations in the inducing cause, or as partly due to induction, and partly to the *permanent* magnetism of certain portions of the ship's iron; in which latter case the part of the disturbance occasioned by induction was considered to be variable in the manner already described; and the part occasioned by the permanent magnetism to be constant, or nearly so.

Upon the hypothesis of the whole disturbance being occasioned by induced magnetism, its amount in any particular direction of the ship's head should be the same, or nearly so, in north and south dips of equal amount, but should have opposite signs; that is to say, the disturbance which was towards the west when the north end of the needle dipped, should be towards the east when the south end of the needle dipped, and should be to the same amount: and if the further assumption were correct, that the induced magnetism of the ship changed simultaneously with changes in the terrestrial dip, as is known to be the case with soft iron, the disturbance might be altogether (at least approximately) prevented, by a counteracting mass of soft iron disposed suitably in reference to the place of the compass and to the resultant of the ship's magnetic action.

On the supposition that the disturbances were due partly to the induced magnetism of certain portions of a ship's iron, and partly to the permanent magnetism of other portions, the calculation of corrections would become more complex, as terms must be introduced to represent both a variable and a constant effect; and counteraction by means of soft iron would no longer meet the case. But a combination of permanent magnets and of soft iron, each suitably disposed, might, as was supposed, accomplish and preserve an approximate compensation, if the magnets and the permanently magnetic portion of the ship's iron maintained their magnetic relations unaltered, and if the changes of the induced magnetism of the ship were as simultaneous with changes in the terrestrial magnetism as they were presumed to be in soft iron.

The observations which were made on the disturbance of the compass needle of the Erebus and Terror in the river Thames, where the magnetic dip was about 69° *north*, and at Hobarton, where the dip was between 70° and 71° *south* (the ships in both cases having remained several months in the localities of the respective dips), showed that in the interval between the two sets of observations a change had taken place in the disturbance, corresponding in kind, and almost precisely in degree, with the hypothesis of induced magnetism. The disturbance was in the opposite direction at Hobarton to what it had been in the Thames: in the one case the north pole of the compass needle was drawn towards the fore part of the ship, and in the other case the south pole. The amount of disturbance in the one direction in the Thames, and in the opposite direction at Hobarton, was so nearly the same—the terrestrial dip having also nearly the same numerical value at the two stations, but with opposite signs,—as fully to bear out the inference, that in those two ships the chief part

if not the whole of the disturbance of the compass was occasioned by induced magnetism.

Such being the case, it might naturally have been expected that formulæ founded on M. Poisson's investigations regarding the induced magnetism of ships, which represented so well the change that had taken place between England and Van Diemen Island, would also represent the disturbance which had been found to take place at stations visited by the ships in the intermediate passage; and that the result of azimuths observed in the same geographical position of the ship, with her head on different points of the compass, would be brought into agreement with each other, at any period of the voyage, by corrections computed by the formulæ of which the variable coefficients were taken as varying with the changes of the terrestrial dip.

Such however was by no means the case. A table of corrections was computed by the appropriate formulæ for each of the thirty-two points and for every degree of north and south dip; the values of the coefficients in the formulæ being derived from the observations in the Thames and at Hobarton; and those which were variable being assumed, in conformity with the hypothesis, to vary according to the dip. On comparing this table with the observations at intermediate times and stations, it was immediately perceived that in order to suit the table to the observations, it was necessary to enter the table, not with the dip at the time and place of the observation to be corrected, but with a dip which had been passed through by the ship several days antecedently; and on a more close and general examination, this was found to be the systematic and consistent result of the whole comparison.

This result by no means contradicts the inference previously drawn, and based on the observations in the Thames and at Hobarton, viz. that the disturbances in the Erebus and Terror were chiefly if not wholly ascribable to induced magnetism; for it is quite conceivable that portions of a ship's iron, which are not permanently magnetic on the one hand, nor perfectly soft so as to undergo instantaneous change with changes of the dip on the other hand, may still derive magnetism by induction from the earth, which may conform *gradually* rather than *instantaneously* to the changes of terrestrial magnetism corresponding to changes of the ship's place; so that after an interval of greater or less duration, the variation of the magnetic state which is characteristic of induced magnetism may be as complete in such portions of the iron as in those in which the change takes place instantaneously: but it is inconsistent with the proposed counteraction of the induced portion of the disturbance by means of soft iron, unless a degree of retentive force could be given to the soft iron which should be precisely equivalent to that of the general resultant of all the iron in a ship which is not permanently magnetic; and which doubtless varies considerably in different ships.

Since 1843, when the fifth number of the Magnetic contributions was printed, I have examined the observations made in several ships which have passed from one hemisphere to the other, and have found them, without a single exception, cor-

responding in character to those of the Erebus and Terror. When a ship is rapidly changing her geographical position, or when she has just arrived in port after making a recent considerable change of geographical position, her magnetism is always in arrear (if I may so express myself) of the change which would be equivalent to the change in the terrestrial dip; but after she has remained in the same locality a period, which may be supposed to depend in some measure on the rapidity and amount of the change of dip that she has passed through, as well as on the particular degree of retentiveness of her iron, I have found in all cases that have hitherto come under my examination, that the amount of disturbance in north and south dips of equal amount becomes ultimately the same, but with the opposite sign.

The practical bearing of these conclusions is considerable. If the whole disturbance be due to induced magnetism,—and if when changes of geographical position are made, the disturbance is found to conform fully to the laws of induced magnetism after an interval which may be considered brief in comparison with a ship's frequent detention in different places, whilst during that interval it is in continual progress thereto,—permanent magnets are wholly inappropriate for the purpose of supplying a compensating force in ships making considerable changes of geographical position; and if correctly applied in the one hemisphere they may even double the error they were intended to correct when the ship is in the other hemisphere. On the other hand, the compensation by means of soft iron, if correctly applied in the one hemisphere, may become *after a time* an equally approximate compensation in the other hemisphere; but in the passage from the one hemisphere to the other, and generally when a ship is changing rapidly her geographical locality, the compensation may be very imperfect; and errors thus resulting are the more likely to be prejudicial when a compass is supposed to be compensated, because the habit of watching for them is then impaired. The counteraction of the disturbance by the introduction of a magnetic force which should at all times counterbalance that of the ship, would seem therefore to be a more complicated problem than it has been supposed to be: for neither permanent magnets, nor iron which changes simultaneously, can afford separately or conjointly suitable compensation for disturbances which are in part at least a function of time.

Nor are these conclusions without a practical bearing on the applicabilities of the formulæ which have been derived from theoretical investigations, for the purpose of supplying corrections for the disturbing influence of a ship's iron on her compass, and on other magnetical instruments employed on board ship: for it becomes necessary to take into account, in addition to the two qualities of iron previously recognised and for which terms were provided, a third portion which is of an intermediate quality between the other two, and of which the magnetism is neither permanent on the one hand, nor are its changes simultaneous with or immediately consequent on changes of the terrestrial dip. Even in the most simple case of the disturbances being occasioned chiefly or wholly by induced magnetism, the data which are

furnished by swinging a ship in harbour, even if repeated in more than one locality, must be insufficient to furnish corrections for the observations which may be made at sea in passages from port to port, if unaccompanied by experimental data furnished from time to time during the passages themselves.

Seeing therefore the importance of the conclusions to which I have been led, I have thought it desirable to collect together in one point of view on the present occasion all the observations which were made in the Erebus for the purpose of examining the disturbance of the compass, during the three years in which she was employed in the Antarctic Expedition, and to enter on a somewhat detailed discussion of them.

TABLE I.—Disturbance of the Compass in H.M.S. Erebus.

\+ Implies a disturbance of the North end of the needle towards the West;
— towards the East.

Direction of ship's head.	Gillingham, September 1839.	Port Praya, November 1839.	St. Helena, February 1840.	Cape of Good Hope, April 1840.	Kerguelen Island, July 1840.	Hobarton, October 1840.	Hobarton, June 1841.	Falkland Islands, August 1842.	Cape of Good Hope, April 1843.	Direction of ship's head.
N. by W.	+1° 12′	+0° 27′	−0° 02′	+0° 16′	−0° 27′	−0° 35′	−1° 28′	−0° 04′	−0° 37′	N. by W.
N.N.W.	+2 01	+0 20	−0 27	+0 10	−1 08	−0 29	−2 15	−0 34	−1 04	N.N.W.
N.W. by N.	+2 10	+0 52	−0 34	+0 02	−2 07	−1 43	−2 48	−0 51	−1 15	N.W. by N.
N.W.	+3 03	+1 15	−0 40	−0 03	−2 02	−1 59	−3 09	−1 02	−1 42	N.W.
N.W. by W.	+3 28	+1 25	−1 03	−0 15	−2 27	−2 47	−3 27	−1 01	−2 01	N.W by W.
W.N.W.	+3 51	+1 05	−0 25	−0 33	−3 12	−3 07	−4 04	−1 49	−2 35	W.N.W.
W. by N.	+4 09	+1 15	−0 29	−0 51	−3 36	−3 37	−4 47	−2 10	−2 54	W. by N.
W.	+4 19	+1 33	−0 32	−1 09	−3 41	−4 03	−5 13	−2 16	−3 09	W.
W. by S.	+4 40	+1 49	−0 12	−1 14	−3 56	−4 02	−5 11	−2 21	−3 17	W. by S.
W.S.W.	+4 03	+1 24	+0 09	−1 05	−4 06	−4 16	−4 55	−2 21	−3 09	W.S.W.
S.W. by W.	+3 24	+1 34	+0 08	−1 06	−3 47	−4 27	−4 33	−2 14	−2 52	S.W. by W.
S.W.	+2 45	+0 26	+0 04	−0 52	−3 23	−3 55	−3 54	−1 58	−2 27	S.W.
S.W. by S.	+2 08	+0 09	+0 14	−0 40	−2 34	−3 24	−3 13	−1 43	−1 52	S.W. by S.
S.S.W.	+1 34	−0 02	−0 01	−0 02	−1 53	−2 18	−2 30	−1 17	−1 12	S.S.W.
S. by W.	+0 52	+0 10	−0 09	+0 16	−0 45	−1 27	−0 34	−0 39	−0 07	S. by W.
S.	+0 28	−0 39	−0 29	+0 39	+0 22	−0 38	+0 29	0 00	+0 33	S.
S. by E.	−0 19	−0 32	−0 24	+1 14	+1 10	+0 21	+2 18	+0 44	+1 07	S. by E.
S.S.E.	−0 48	−0 42	−0 30	+1 26	+2 05	+0 39	+2 52	+1 13	+1 45	S.S.E.
S.E. by S.	−1 23	−0 25	−0 25	+1 41	+2 50	+1 24	+3 37	+1 41	+2 08	S.E. by S.
S.E.	−1 53	−1 09	−0 21	+2 53	+3 21	+1 56	+4 20	+1 55	+2 31	S.E.
S.E. by E.	−2 21	−1 25	−0 21	+2 01	+3 51	+1 46	+4 46	+2 07	+2 51	S.E. by E.
E.S.E.	−2 50	−1 18	−0 06	+1 43	+4 12	+3 29	+5 31	+2 19	+3 15	E.S.E.
E. by S.	−3 17	−1 44	+0 13	+1 34	+3 53	+3 23	+5 06	+2 16	+3 10	E. by S.
E.	−3 42	−1 56	+0 32	+1 15	+3 48	+3 50	+4 53	+2 07	+2 46	E.
E. by N.	−4 53	−2 40	+0 55	+1 02	+3 31	+4 06	+4 32	+1 54	+2 30	E. by N.
E.N.E.	−3 46	−2 47	+0 57	+1 51	+3 02	+3 41	+3 52	+1 44	+2 15	E.N.E.
N.E. by E.	−3 18	−2 30	+0 48	+0 31	+2 13	+3 33	+3 31	+1 16	+1 59	N.E. by E.
N.E.	−2 59	−2 10	+1 11	+0 22	+2 10	+3 23	+2 54	+0 51	+1 33	N.E.
N.E. by N.	−2 16	−2 12	+0 52	+0 11	+1 32	+3 01	+2 25	+0 41	+1 15	N.E. by N.
N.N.E.	−1 39	−1 53	+0 28	+0 01	+1 01	+2 37	+1 15	+0 41	+0 43	N.N.E.
N. by E.	−0 49	−1 17	+0 17	+0 24	+0 23	+2 17	+0 23	+0 28	+0 15	N. by E.
N.	+0 06	−0 56	+0 05	+0 24	−0 08	+1 12	+0 41	+0 13	−0 20	N.

From the observations in September 1839, at Gillingham in the River Thames (where the ship had been stationary for many months), a table was formed by the well-known formulæ derived from Poisson's fundamental equations applicable to in-

duced magnetism, giving the corrections which, on that hypothesis, and on the further supposition that the changes in the induced magnetism of the ship were simultaneous with those of terrestrial magnetism, should have corresponded with the disturbance on each of the thirty-two points of the compass under every degree of the terrestrial dip. On examining, by means of this table, the number of degrees of dip by which it was necessary to go back from the dip at the place of observation, in order to obtain from the table corrections corresponding to the disturbances at the stations where the ship was subsequently swung, I find that at Port Praya, where the dip was $+45^\circ\ 32'$, and after a passage of thirty-six days from the British Channel, where the dip was about $+69^\circ$, that the ship's magnetism, instead of corresponding to a dip of $+45^\circ\ 32'$, did in fact correspond to a dip of about $+51^\circ\frac{1}{2}$; the arrear being about 6°.

At St. Helena, where the dip was about -20°, and where the ship had arrived after a passage of about seventy-nine days from Port Praya, during which she had passed from north into south dip, the arrear was between thirty and forty degrees—the tabular corrections for 20° *north* dip corresponding more nearly with the differences of the azimuths observed at St. Helena with the ship's head on different points, than did the tabular corrections for 20° *south* dip; so that the effect of the employment of the latter would manifestly have been to have increased the evil which they were intended to correct.

At the Cape of Good Hope, where the dip was -53°, and after an interval of thirty-eight days from her departure from St. Helena, the arrear appears to have been about twelve degrees.

At Kerguelen Island, where the ship arrived after a passage of forty days from the Cape, but where she remained in harbour about fifty days before the disturbance experiments were made, the tabular corrections had overtaken the terrestrial dip, although the latter had increased from -53° at the Cape to -70° at Kerguelen Island; above one hundred days had elapsed between the experiments in -53° and those in -70° of dip, of which less than half the number were occupied in making the passage from the dip of -53° to that of -70°, and the rest were passed at the anchorage in -70°. From Kerguelen Island the Erebus proceeded to Hobarton, where the dip was the same, within a degree, as at Kerguelen Island, being $-70^\circ\ 40'$, and where, as I have already stated, the disturbances were found to be, both in kind and amount, very nearly such as might have been computed beforehand from the observations in the Thames, by the formulæ which apply to induced magnetism susceptible of instantaneous change, the tabular corrections compensating the disturbances within the limits of the usual errors of observation.

From Hobarton the Erebus proceeded, in November 1840, to the high geographical latitudes of the southern hemisphere, and remained for some months in south dips much exceeding that at Hobarton, to which station she returned in April 1841. On the 29th of June 1841, being about eleven weeks after her arrival in harbour, observations were made on the disturbances of the compass on each of the thirty-two points.

The arrear was now found to be on the side of the higher dips, though probably to a much less amount than might have been the case had the observations been made at an earlier period after her return; the tabular corrections which most nearly correspond to the observed disturbances are those of the dip $-71° 28'$ instead of $-70° 40'$.

The expedition left Hobarton a second time in July 1841, passing the following (Antarctic) summer again in the regions of high southern dip, and returning to the Falkland Islands in April 1842, where the dip was between $-52°$ and $-53°$; the observations on the disturbances of the compass were made in August, being about four months after the ship arrived; an arrear however still remained on the side of the high dips in which several months had been passed previously to her arrival; the tabular corrections corresponding to the disturbances are those belonging to a dip of between $-56°$ and $-57°$, instead of between $-52°$ and $-53°$.

From the Falkland Islands the Erebus sailed once more for the high latitudes in December 1842, returning, on this occasion, to the Cape of Good Hope in April 1843. She had now been in localities of higher southern dip than that of the Cape during nearly the whole of the three years which had elapsed since her former visit to the Cape, and she had passed the three months immediately antecedent to her second arrival, in dips varying from $-60°$ to $-65°$, that of the Cape at the same period being $-53° 30'$. The disturbances of the compass were examined on the 20th of April, being a very few days after her arrival at the Cape, and I find that the tabular corrections corresponding to them are those belonging to a dip of about $-63° 30'$. The arrear on this occasion was therefore about 10° on the side of the higher dips, it having been about 12° on the side of the lower dips when the ship arrived, in 1840, at the same station from localities of lower dip.

The experiments at the Cape in April 1843 were the last, I understand, that were made in the Erebus during the progress of the voyage, for the purpose of examining the influence of the ship's iron on her compass by the usual process of swinging the ship: and by an unfortunate misunderstanding, the repetition of the experiments on the return of the vessel to the Thames, which had been ordered by the Admiralty, and was fully designed to have taken place by Sir James Ross, was also omitted. It appears therefore that in every instance in which the proper experiments were made, the disturbances were found to be consistent with the hypothesis of an induced magnetism conforming *gradually* to the changes in the terrestrial magnetic phenomena occasioned by the changes in the ship's geographical position, but not changing *simultaneously* with those changes.

But whether the hypothesis of a gradual conformity of a part of the ship's iron, instead of an instantaneous conformity of the whole, to changes of the terrestrial dip, be or be not the true explanation of the facts which have been thus pointed out, the facts themselves are highly deserving of consideration by those to whom the correction of compass errors is of consequence; the anomalies which present themselves to any previously entertained systematic view are of too large amount, as well as too consistent on the different points, both in the observations at sea and in harbour, to

be ascribed either to errors of observation or to accidents; and the prominency which has been given to them on this occasion will not be misplaced, if it should serve to impress upon those who have the power of carrying out practical suggestions, the importance of giving a sufficient trial to the method proposed by Mr. Archibald Smith in the eighth number of the Magnetic Contributions, whereby the variable term in the correction formula may be at all times determined experimentally at sea, by deflections of the compass needle obtained with the ship's head on two opposite points of the compass. The observations needed are extremely simple, require no unusual circumstances of weather and no reference to celestial objects, and need occupy but a very few minutes.

Mr. Smith has shown that the variable term may also be determined at sea by observations of azimuths with the ship's head placed on the points of greatest disturbance; but the deflection method promises to be even more simple than that by azimuths. By the addition of a brass bar attached at right angles to the prism and sight vane of the azimuth ring of the standard compass, deflecting magnets may be temporarily fixed at a convenient distance from the compass needle, and the deflections measured with the ship's head on two opposite points; as was first practised by Captain (then Lieut.) Henry Clerk, R.A., F.R.S., in his Antarctic voyage*.

If this method of determining the variable coefficient in the correction formulæ be found to answer its purpose on a further and sufficient trial, the correction of the disturbances occasioned by the ship's iron might be still further simplified by the formation of tables of each term for every probable value of the coefficients, when the only calculation remaining to be made would be the addition of the quantities to be taken out from the tables. In wooden ships, two terms, and consequently a single addition, would probably, in most cases, be sufficient for the whole amount of the correction†.

With reference to the corrections which we have now occasion to employ for the declinations observed in the Erebus in her passage from England to the Cape of Good Hope, we have the following values of the constant coefficients A, D and E in the formula (6.)‡, derived from the observations on the thirty-two points of the compass, at the several stations at which these observations were repeated, by the equations (16.), (19.) and (20.)§.

	A.	D.	E.
Gillingham	+15′	+16′	− 3′
Port Praya	−23	+24	− 8
St. Helena	——	+27	+ 3
Cape of Good Hope, 1840	+23	+23	+15
Mean	+ 5	+22	+ 2

* Philosophical Transactions, 1846, p. 347.

† Whilst these pages were in the press, tables such as are here referred to have been drawn up and printed under the direction of the Admiralty in a tract entitled "Directions for ascertaining at any time, whether at sea or in harbour, the *changing* part of the Deviation in the Compass occasioned by the Ship's Iron."

‡ Philosophical Transactions, 1846, p. 348.

§ Ibid. pp. 350 and 351.

From the small amount of the mean value of A, we may infer that the iron which affected the compass was distributed systematically, or nearly so, on either side of the midship line; the variations in the values at different stations are greater than could be wished, but they have no regular appearance, and may probably be due to accidental circumstances, which in such experiments cannot possibly be wholly guarded against. Considering the small mean value of the coefficient, and the extent of its variations on the different occasions, we may dispense altogether with its further consideration. A similar remark will apply to E; since if its mean value were employed, the maximum effect on the correction would in no instance exceed two minutes. But it is otherwise with regard to D, which has a very sensible value in respect to the whole amount of the correction, especially in low latitudes; and the deductions in regard to it are tolerably consistent at the different stations; I have taken its mean value at $+22'$.

For the variable coefficients B and C, we have not the advantage of possessing the experimental determinations at sea, which have been pointed out as possible to be made on future occasions with the deflecting apparatus: and we must therefore obtain these also from the observations in harbour in the best manner that circumstances will admit.

Commencing with B as the more important, we have the following values at the four stations for the passages between which the corrections are required. (The values are expressed by the sines of the respective arcs):—

	Dip.	B.
Gillingham, September 20, 1839	$+69^\circ\ 05'$	$+\cdot0675$
Port Praya, November 18, 1839	$+45\ 32$	$+\cdot0324$
St. Helena, February 8, 1840	$-20\ 06$	$+\cdot0073$
Cape of Good Hope, April 4, 1840	$-53\ 02$	$-\cdot0219$

If from these values of B we seek intermediate values corresponding to interme diate dips or times, we are obliged, for the reasons already stated, to have recourse to some more or less arbitrary supposition. It has been already shown that the intermediate values cannot be computed directly from the observations of the dip; and if the explanation which has been proposed be correct, it may not be unreasonable to regard the variation of this coefficient as a function of the time elapsed rather than of the change of dip. In two of the three passages at least, viz. from the British Channel to Port Praya and from St. Helena to the Cape, this might be the more safely assumed, because the ship's progress with respect to the terrestrial dip was uninterrupted, in the first case to diminishing north dips, and in the second to diminishing south dips. In the first case we have a change in B of $\cdot0351$ in fifty-nine days, or $\cdot00059$ per diem, and in the second of $\cdot0292$ in fifty-six days, or $\cdot00052$ per diem. In the voyage from Port Praya to St. Helena the progress in respect to the change of dip was uninterrupted from the period of departure from Port Praya on the 21st of November 1839 to the 2nd of January 1840, the dip having diminished in that interval from $+45^\circ\ 32'$ at Port Praya to between -29° and -30°. But from the 2nd of January the ship, in beating

up to St. Helena, gradually though interruptedly, diminished the southerly dip, which at St. Helena is about $-20°$. The 2nd of January may therefore be regarded as dividing this part of the voyage into two portions in respect to the changes of B. As the daily rates of change deduced above for the passages from the Thames to Port Praya and from St. Helena to the Cape (·00059 and ·00052) differ so little from each other, we may not unreasonably take their mean as applicable to the first division of this part of the voyage, or for that division in which the change of dip was continuous and uninterrupted. This gives as the value of B on the 2nd of January +·0074. Now at St. Helena we find it by experiment +·0073; on this assumption consequently the magnetism of the ship would have remained nearly stationary from the 2nd of January to the arrival at St. Helena, which is by no means an improbable supposition.

We may derive intermediate values of C in a similar manner*. This coefficient is however of very minor importance.

It will of course be understood that this mode of deriving these coefficients is one which would only be adopted in the absence of more satisfactory data; and fortunately in the part of the globe for which the corrections are required the values of B and C are less significant than in the higher latitudes. The observations themselves, however, furnish a test by which the appropriateness of this or of any other hypothesis proposed for their correction may be judged, viz. by the measure of agreement into which the corrections bring observations made on the same day or near the same spot with the ship's head on different points. Without entering into details, it may be stated, generally, that the corrections computed by the formula (6.) with the value of the coefficients as above stated appear to bear this test very satisfactorily; the observations thus corrected becoming much more accordant with each other than either when uncorrected, or than when corrected by the same formula with its variable coefficients made to vary in accordance with the dip.

Determinations in H.M.S. Erebus, in 1842 *and* 1843, *between Cape Horn and the Cape of Good Hope.*

For the corrections of the declinations observed in the Erebus in 1842–43 between Cape Horn and the Cape of Good Hope, we have seen, p. 184, that the value of the constant coefficient D as derived from the experiments in the River Thames and Port Praya in 1839, and at St. Helena and the Cape of Good Hope in 1840 was $+22'$; for the experiments at the Falkland Islands in August 1842, $D=+23'$, and from those at the Cape in 1843, $+24'$; I have made no alteration therefore in the general table of corrections which was computed, as already noticed, with $+22'$.

For the variable coefficients B and C we possess no other data, for the period now under consideration, than the values derivable from the experiments in the Falk-

* Values of C derived from the harbour observations:—

Gillingham	−·0036
Port Praya	−·0046
St. Helena	−·0033
Cape of Good Hope	−·0044

land Islands in August 1842, and at the Cape of Good Hope in April 1843; from these we obtain,—

At the Falkland Islands . . . . $B=-\cdot0377$; $C=+\cdot0009$.
At the Cape of Good Hope . . . $B=-\cdot0517$; $C=-\cdot0040$.

It has been already noticed that the term $\sqrt{B^2+C^2}$, derived from these values, was on both occasions numerically greater than would have been assigned from the dips at the respective stations, and the values of the same coefficients at other stations where the ship had remained sufficiently long for the full development of the changes in its induced magnetism corresponding to changes of geographical position. The experiments at the Falkland Islands and at the Cape of Good Hope, afford however the best indication which we possess of the magnetic state of the ship in the interval comprised between their respective dates, and must be taken as the foundation of the corrections during that interval. In September 1842 the Erebus quitted Port Louis in the Falkland Islands for Cape Horn, and after remaining some weeks at St. Martin's Cove, where the dip was between $-58°$ and $-59°$, returned in November to the Falkland Islands; from whence she sailed immediately afterwards to resume the magnetic survey of the higher latitudes, arriving at the Cape of Good Hope in April 1843. In the whole interval between August 1842 and April 1843, the ship was at no time in a lower dip than that at the Falkland Islands, and we may presume therefore, with much probability, that the $\sqrt{B^2+C^2}$ was in no part of the interval less than its value at Port Louis. We have thus a minimum value for this term. During January 1843 the dips observed in the Erebus ranged, in different localities, from $-60°$ to $-63°$. In February from $-58°$ to $-62°$; in the first week of March a favourable opportunity presenting itself for pressing to the southward, the dip increased to between $-65°$ and $-66°$; but from the 8th of March it progressively diminished until the arrival at the Cape on the 6th of April. The experiments made at the Cape on the 20th of that month gave a value of $\sqrt{B^2+C^2}$, corresponding to $-63°$, or thereabouts. It is not probable from this review that $\sqrt{B^2+C^2}$ was at any time *much* higher than it was found at the Cape; it may possibly have been a little higher for some days in March, but I have thought it safer to keep within the limits which were actually observed than to assume a conjectural maximum; and in correcting the declinations of this period I have accordingly taken the value of $\sqrt{B^2+C^2}$ observed at Port Louis as applicable until the Erebus sailed for the higher latitudes in December 1842, and have then increased it uniformly and progressively with the time until the first week in January 1843, when the dip was $-63°$, corresponding to the highest observed value of $\sqrt{B^2+C^2}$; and I have used that value thenceforward until the arrival at the Cape, where it accorded with the experiments.

By the following memorandum with which I have been furnished by Mr. Tucker, Master of the Erebus, it appears that the standard compass of that ship had an index error of considerable amount during this portion of the voyage. I have not been able to learn anything satisfactory in regard to the cause of this error, which did not exist when the compass was tried by Captain Johnson, R.N., before the expedition

quitted England; nor could it have existed when the ship was swung in the River Thames, at Port Praya, or at the Cape of Good Hope in 1840, or it would have appeared to its full amount in the value derived for the coefficient A. The evidence, however, afforded by the consistent results of the several trials that were made both at the Falkland Islands and at St. Martin's Cove in 1842, and both on shore and on board, leaves no doubt of the existence of index error at that period.

I cannot find that any trial was made of the index error of this compass on the arrival at the Cape in April 1843; but in the neighbourhood of the Cape the Erebus crossed the track of the Pagoda, the observations of which ship are published in the Philosophical Transactions for 1846, Part III., and the declinations observed in the two ships agree when the index error observed at the Falkland Islands is employed for the compass of the Erebus, but would disagree to an amount of nearly two degrees if that correction were not employed.

Mr. Tucker's memorandum is as follows:—

"The compass error of the standard compass of the Erebus was ascertained at Port Louis in the Falkland Islands, on the 13th of August 1842, in the following manner. The compass with its card CCH was taken on shore, and its tripod was fixed over the spot on which the transit had been established; the bearings of the N. and S. meridian marks were then taken with the compass as follows:

North mark . . . . . N. 15° 36′·8 W.
South mark . . . . . S. 15° 40′ E.

The true declination was 17° 33′ E. in the month of August by the declinometers of the observatory; the error of the standard compass was therefore 17° 33′ − 15° 38′·5 = 1° 54′·5, or the north end pointed 1° 54′·5 to the west of the true magnetic north. The compass was taken again on shore at the same place in September and December, and at St. Martin's Cove in November, and the compass error was tried in the same way, and was found on all those occasions to be within a few minutes the same as that above stated. Also when the ship was swung at Port Louis on the 19th of August 1842, the sum of the declinations observed with the standard compass in its usual place on board, on the thirty-two points, divided by thirty-two, made a mean declination of −15° 39′·3; the true magnetic declination in the same month by the declinometer was −17° 33′, whence the compass error equals 1° 53′·7 to the westward of north."

In conformity with this memorandum I have employed −1° 54′ as an index correction from August 1842 to April 1843.

Determinations in H.M.S. Terror, in 1842 *and* 1843, *between Cape Horn and the Cape of Good Hope.*

The disturbance of the compass of the Terror was examined at the Falkland Islands on the 17th of August 1842, and at the Cape of Good Hope on the 20th of April 1843, by azimuths observed with the ship's head successively on the thirty-two points. Assuming the mean of the azimuths on the thirty-two points to give the true

declination (*i. e.* the coefficient A=0), the disturbance on the several points are as follows, viz.—

TABLE II.—Disturbance of the Compass in H.M.S. Terror.

Ship's head.	Disturbances towards the west.		Ship's head.	Disturbances towards the west.	
	Falkland Islands, Aug. 17, 1842.	Cape of Good Hope, April 20, 1843.		Falkland Islands, Aug. 17, 1842.	Cape of Good Hope, April 20, 1843.
N.	+0° 18′	−0° 58′	S.	−0° 16′	+0° 44′
N. by W.	−0 02	−1 3	S. by E.	−0 08	+1 56
N.N.W.	−0 17	−1 6	S.S.E.	0 00	+3 1
N.W. by N.	−0 48	−1 22	S.E. by S.	+0 47	+3 2
N.W.	−1 19	−2 20	S.E.	+1 35	+3 5
N.W. by W.	−1 49	−2 12	S.E. by E.	+2 17	+3 3
W.N.W.	−1 47	−3 14	E.S.E.	+3 04	+3 4
W. by N.	−2 07	−3 35	E. by S.	+2 33	+3 22
W.	−2 30	−3 36	E.	+2 46	+2 35
W. by S.	−2 21	−3 8	E. by N.	+2 27	+2 27
W.S.W.	−2 12	−2 35	E.N.E.	+1 58	+1 53
S.W. by W.	−2 21	−2 1	N.E. by E.	+1 39	+1 23
S.W.	−1 33	−1 33	N.E.	+1 13	+1 8
S.W. by S.	−1 05	−1 26	N.E. by N.	+1 11	+1 1
S.S.W.	−0 47	−1 22	N.N.E.	+0 34	+0 30
S. by W.	−0 45	−0 9	N. by E.	+0 27	−0 27

From these we have D=+17′ and E=+6′; also $\sqrt{B^2+C^2}=-\cdot040$ at the Falkland Islands, and −·054 at the Cape. For the reasons assigned in the case of the Erebus, I have taken −·040 as applicable until the Terror sailed to the higher latitudes in December 1842, and have then increased it uniformly and progressively with the time until the first week in January 1843, when the south dip was greatest; and from this date until the arrival at the Cape I have employed −·054 (observed at the Cape), which was the greatest observed value of this term.

The compass employed in this portion of the Terror's voyage was made by CUMMINS, and had two cards, a light and a heavy one, the latter being used exclusively in very bad weather. In a memorandum which I received from Captain CROZIER, it is stated that the index errors were examined at the observatory in the Falkland Islands on the 23rd of August 1842, and found to require corrections, with the light card of +1° 13′, and with the heavy card of −0° 40′. The cause of these errors does not appear to have been examined either during the voyage or after the return to England. The error of the light card, which was the one generally used, is in the opposite direction to the error assigned to the compass of the Erebus examined at the same time; and it is remarkable that throughout this portion of the voyage in which the two ships were always in company, the declinations observed in the Erebus are generally still more easterly than those of the Terror after the corrections for the compass error are applied, and that this disagreement would be greater if the corrections were not so applied. I have therefore felt the less hesitation in admitting and employing compass errors of such magnitude, the cause of which does not appear to have undergone investigation; but I cannot avoid expressing the hope that as the state of

the compasses supplied to Her Majesty's navy has at length received from the Admiralty the attention which was so long and so greatly wanted, and since a department has been expressly instituted for their proper examination and care, errors of such magnitude, where no such errors need exist, may no longer be found to occur*.

I would also take this occasion to remark, that in examining the disturbance caused by the ship's iron at the spot in which the standard compass is placed by the process of swinging the ship, the standard compass itself should be employed, and not, as appears to have been sometimes done, another compass substituted for that particular occasion. When compass errors exist, the coefficient A derived from the observations with one compass are inapplicable to the observations of another compass having a different compass error. Also, when circumstances permit, it is preferable that the actual disturbance on each point should be ascertained independently of that on other points, as is done when the bearing of an object is observed whose correct magnetic bearing is known or subsequently determined. Disturbances supposed to be ascertained, by comparing azimuths observed on each point with the means of the azimuths observed on all the points, are liable to be in error to the full amount of the value of the coefficient A, whether that value arise from compass error or from the disturbing influence of the iron.

Determinations made in H.M.S. Thunder, in a passage from Nassau, New Providence, to England in 1841, *by Captain* Edward Barnett, *R.N.*

The observations in the Thunder were made with one of the Admiralty compasses, fitted as a standard compass. The disturbance occasioned by the iron was examined at Nassau in March 1841, immediately after the arrival of the ship from England, and at Gillingham in the River Medway, about the 1st July of the same year on her return to England. The observations were as follows, viz.—

Table III.—Disturbance of the Compass in H.M.S. Thunder.

Ship's head.	Disturbances towards the west.		Ship's head.	Disturbances towards the west.	
	Nassau.	Gillingham.		Nassau.	Gillingham.
	° ′	° ′		° ′	° ′
N.	−0 5	−0 15	S.	+0 23	+0 38
N. by W.	+1 19	+1 00	S. by E.	+0 1	−1 17
N.N.W.	+1 16	+1 59	S.S.E.	−0 34	−1 25
N.W. by N.	+2 18	+3 38	S.E. by S.	−0 43	−3 35
N.W.	+2 48	+5 02	S.E.	−1 22	−4 2
N.W. by W.	+3 32	+6 2	S.E. by E.	−2 1	−4 23
W.N.W.	+3 53	+6 6	E.S.E.	−2 36	−5 19
W. by N.	+3 45	+6 12	E. by S.	−3 9	−5 50
W.	+3 52	+6 15	E.	−3 19	−6 16
W. by S.	+3 44	+6 51	E. by N.	−3 26	−5 44
W.S.W.	+3 21	+5 15	E.N.E.	−3 34	−6 28
S.W. by W.	+2 59	+5 42	N.E. by E.	−3 12	−5 57
S.W.	+2 37	+5 2	N.E.	−2 52	−4 46
S.W. by S.	+1 55	+3 32	N.E. by N.	−2 16	−3 48
S.S.W.	+1 52	+2 40	N.N.E.	−1 56	−2 51
S. by W.	+0 34	+2 5	N. by E.	−0 27	−0 51

* When the Erebus left England the prism by which the graduation of the card of the Admiralty compasses

From these we obtain A=+8′; D=+14′; E=−2′; B at Nassau =+·062, and at Gillingham +·111; C at Nassau =−·006, and at Gillingham =−·007.

From Nassau the Thunder passed immediately into dips on the coast of America higher than those in the subsequent portion of her voyage, or than the dip at Gillingham. The variable part of the disturbance therefore, probably, increased rapidly after leaving Nassau, and may have been greater whilst the ship was off the coast of America than when examined at the termination of the voyage. Having no intermediate data, however, I have not ventured to exceed the maximum observed value of $\sqrt{B^2+C^2}$, but have commenced with +·062, the observed value at Nassau on the 1st of May, and increased it uniformly with the time to +·111, the observed value at Gillingham, and have supposed it to have attained the latter value on or about the 1st of June, when the ship had been a fortnight in dips exceeding that in the Thames.

Determinations in the Prince Regent Transport, on the passage from England to Canada in 1842, *by Lieutenant (since Captain)* J. H. Lefroy, *R.A.*

These observations were made by Lieut. Lefroy when proceeding to Canada in 1842 to take charge of the Magnetic Observatory at Toronto. By direction of the Hydrographer, Lieut. Lefroy was furnished with one of the Admiralty compasses, which was fixed as a standard in the usual manner. The Prince Regent was swung at Greenhithe by Captain Johnson, R.N., from whom I received the following table of deviations.

Table IV.—Disturbance of the Compass in the Prince Regent Transport.

Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.
N. by W.	+0° 45′	W. by S.	+2° 40′	S. by E.	+0° 05′	E. by N.	−2° 00′
N.N.W.	+1 55	W.S.W.	+2 20	S.S.E.	−0 10	E.N.E.	−1 45
N.W. by N.	+2 05	S.W. by W.	+2 05	S.E. by S.	−0 35	N.E. by E.	−1 35
N.W.	+2 15	S.W.	+2 00	S.E.	−0 35	N.E.	−1 05
N.W. by W.	+2 15	S.W. by S.	+1 35	S.E. by E.	−1 05	N.E. by N.	−0 25
W.N.W.	+2 25	S.S.W.	+1 15	E.S.E.	−2 00	N.N.E.	−0 15
W. by N.	+2 30	S. by W.	+1 05	E. by S.	−2 05	N. by E.	−0 10
W.	+2 25	S.	+0 25	E.	−2 05	N.	+0 05

From this table we have the following values of the coefficients:—

Permanent coefficients { A +27′ ; D + 5 ; E +10 } Variable coefficients { B +·0389 ; C −·0001 }

was read, had a motion of adjustment to suit different eyes. An adjustment of this nature was found liable to introduce errors, and has since been discontinued. The prisms are now fixed, immoveably, at a distance from the card adapted for eyes of ordinary vision.

Circumstances did not permit the Prince Regent to be swung on her arrival at Quebec, and we have no other means of assigning the variations of B (C being so small that it may be disregarded) than by assuming it to have varied as the tangent of the dip, which increased from 69° in the Thames to 79° at the entrance of the River St. Lawrence. Upon this supposition $B=\frac{\cdot 0389 \tan \theta'}{\tan 69^\circ}=\cdot 015 \tan \theta'$, θ' being the dip at the place of observation; the deviations on the several points in different dips are then given by

$$\sin \delta = 27' + \overline{\cdot 0149 \tan \theta} \sin \zeta' + 5' \sin 2\zeta' + 10' \cos 2\zeta',$$

and the corrections have been calculated accordingly.

They appear generally to reconcile the results of the observations on the different courses very satisfactorily.

Determinations in H.M.S. Philomel, in a passage from Monte Video to England in 1846, by Captain SULIVAN, *R.N.*

The observations of Captain SULIVAN, R.N. were made in a passage from Monte Video to England in 1846 in H.M.S. Philomel. The error of the compass with the ship's head on different points was examined at Monte Video on the 14th of September 1844, and at Plymouth on the 10th of June 1846, as follows:—

TABLE V.

Disturbance of the Compass in H.M.S. Philomel, Monte Video, September 14, 1844.

Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.
N.	−0° 57′	W.	−0° 40′	S.	+0° 16′	E.	+0° 03′
N. by W.	−0 58	W. by S.	−0 50	S. by E.	+0 39	E. by N.	−0 12
N.N.W.	−0 56	W.S.W.	−0 48	S.S.E.	+0 49	E.N.E.	−0 26
N.W. by N.	−0 50	S.W. by W.	−0 38	S.E. by S.	+0 55	N.E. by E.	−0 26
N.W.	−0 49	S.W.	−0 40	S.E.	+0 55	N.E.	−0 22
N.W. by W.	−0 50	S.W. by S.	−0 25	S.E. by E.	+0 55	N.E. by N.	−0 29
W.N.W.	−0 40	S.S.W.	−0 10	E.S.E.	+0 43	N.N.E.	−0 45
W. by N.	−0 43	S. by W.	+0 03	E. by S.	+0 22	N. by E.	−0 55

Plymouth, June 10, 1846.

Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.
N.	−0° 20′	W.	+1° 27′	S.	−0° 55′	E.	−4° 32′
N. by W.	−0 19	W. by S.	+1 58	S. by E.	−1 09	E. by N.	−4 36
N.N.W.	−0 12	W.S.W.	+0 46	S.S E.	−1 37	E.N.E.	−4 07
N.W. by N.	+0 30	S.W. by W.	+0 34	S.E. by S.	−2 02	N.E. by E.	−4 34
N.W.	+0 52	S.W.	+0 33	S.E.	−1 20	N.E.	−3 16
N.W. by W.	+2 13	S.W. by S.	+0 11	S.E. by E.	−1 27	N.E. by N.	−3 12
W.N.W.	+2 39	S.S.W.	+0 05	E.S.E.	−2 47	N.N.E.	−2 11
W. by N.	+2 30	S. by W.	−0 30	E. by S.	−3 37	N. by E.	−1 26

The mean values of A, D and E, from the preceding observations, are $A=-35'$; $D=+26'$; and $E=+2'$. B at Monte Video $=-\cdot0094$; and at Plymouth $+\cdot0480$; C $-\cdot0095$ at Monte Video, and $-\cdot0031$ at Plymouth. Assuming the values of B to have been the same when the Philomel left Monte Video for England in April 1846 as when she was swung at that station in September 1844, and that its alteration in the passage between Monte Video and Plymouth was uniform in respect to time, we have the change in the variable term of the correction from $-\cdot013$ on the 27th of April 1846 to $+\cdot048$ on the following 10th of June; being at the rate of $+\cdot0014$ for each day. The corrections have been applied in accordance with these values of the coefficients.

Determinations in the Hudson's Bay Company's ship the Prince Albert, in a passage from England to Hudson's Bay and back, in 1846, *by Lieut.* (*since Commander*) T. E. L. Moore, *R.N.*

The observations of Lieut. T. E. L. Moore, R.N., were made in a voyage from the Thames to Moose Fort in Hudson's Bay and back in the summer of 1846, in the Hudson's Bay Company's ship "Prince Albert," in which ship Lieut. Moore embarked by direction of the Admiralty for the purpose of making magnetic observations in compliance with a recommendation to that effect from the Royal Society.

Lieut. Moore was supplied with one of the Admiralty compasses fixed as a standard compass; the ship was swung at Greenhithe on the 4th of June 1846 (before her departure from the Thames), and the influence of the iron examined on the eight principal points of the compass as follows:—

Table VI.—Disturbance of the Compass in the Hudson's Bay Company's ship Prince Albert.

Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.
N.	$-0^{\circ}\ 45'$	W.	$+1^{\circ}\ 12'$	S.	$+0^{\circ}\ 20'$	E.	$-1^{\circ}\ 30'$
N.W.	$+1\ 00$	S.W.	$+0\ 40$	S.E.	$-0\ 40$	N.E.	$-1\ 10$

From whence we obtain $A=-11'$; $D=+12'$; $E=-2'$; $B=+\cdot0236$; $C=-\cdot0099$; the (approximate) inclination being $68^{\circ}\ 52'$.

On the 26th and 27th of August following, the "Prince Albert" being then at the anchorage at Moose Fort in Hudson's Bay, her head was placed successively on seven of the same points (N.W. being omitted on account of difficulties arising from the strength of the tide), and the bearing of an object ten miles distant was observed with the head on each point.

The bearings were as follows:—

N.	S. 65° 00′ W.	S.	S. 65° 00′ W.
N.W.	———	S.E.	S. 63 40 W.
W.	S. 67 00 W.	E.	S. 62 00 W.
S.W.	S. 66 20 W.	N.E.	S. 62 10 W.

The correct magnetic bearing of the distant object from the ship (or that which would have been shown by the ship's compass with her head on each of the points if there had been no local attraction) does not appear to have been observed; we can obtain from the observations therefore only the *differences* of the bearings on the different points. From these we have the half difference of the bearings at east and west, 2° 30′ = (nat. sine ·0436) = $\sqrt{B^2+C^2}$ at Moose Fort, where the (approximate) inclination = 81°·00. Taking the value of the $\sqrt{B^2+C^2}$ at Greenhithe in conformity with the observations there at ·025, and assuming that its variation should be as the tangent of the inclination, we should have $\frac{\cdot 025 \tan 81°\cdot 0}{\tan 68° 52'} = \cdot 062$ as its value at Moose Fort, if the change in the induced magnetism of the ship had kept pace with the change in the terrestrial dip. Here, as in other cases, the variation of $\sqrt{B^2+C^2}$ was in arrear of the change of the inclination, since the observed value ·0436 corresponds to a dip of only 77° 13′.

The whole amount of the deviation in the "Prince Albert" is, however, so extremely small in comparison with vessels of war (the extremes at the east and west points not exceeding 1°½ at the Thames and 2°½ at Hudson's Bay), that we should obtain a sufficient approximation to the true variation of this term, whether we assumed it to vary with the change of dip, or uniformly with the lapse of time. I have taken the latter as the more convenient and ready mode; increasing the coefficient from +·025 on the 4th of June ·0002 per diem, to +·0436 on the 26th of August, and diminishing it at the same rate from the 9th of September, on which day the Prince Albert began to lower the dip on her homeward voyage, to the end of the month when she entered the British channel.

Determinations in H.M.S. Rattlesnake in a passage from England to the Cape of Good Hope, in 1847, *by Captain* Owen Stanley, *R.N.*

The influence of the iron on the Rattlesnake's standard compass was examined at Portsmouth, November 30, 1846, and again at Port Jackson in September 1847, circumstances having prevented a satisfactory repetition of the experiments during a short stay at the Cape of Good Hope.

From the observations at Portsmouth in 1846, as subjoined, we obtain the values of A = −30′; D = +25′, and E = +5′.

TABLE VII.—Disturbance of the Compass in H.M.S. Rattlesnake.

Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.	Ship's head.	Disturbance towards the west.
	° ′		° ′		° ′		° ′
N.	−0 50	W.	+1 30	S.	+0 30	E.	−3 20
N.N.W.	+2 10	W.S.W.	+0 40	S.S.E.	−1 50	E.N.E.	−4 30
N.W.	+3 40	S.W.	+1 50	S.E.	−2 30	N.E.	−3 50
W.N.W.	+2 35*	S.S.W.	+1 10*	E.S.E.	−2 55*	N.N.E.	−2 20

The observations at Portsmouth give B=+·0565 with a dip (approximate) of +68° 40′: by their repetition at Port Jackson in the September following B was found to have changed to −·0305, with a dip (approximate) of −62° 48′. The magnetism of the iron in the Rattlesnake was therefore, for the most part at least, of the nature of induced magnetism; but the value of B in this case, as in others where the ship had materially changed her geographical position, was in arrear on her arrival at Port Jackson of the change which had taken place in the terrestrial dip; it corresponded to a dip of −54° 5′ instead of −62° 48′. Being only concerned at present with the observations as far as the Cape of Good Hope, I have taken the $\sqrt{B^2+C^2}$=+·056 at Portsmouth, which is its value derived from the observations at that port; and having no materials from which the subsequent variation of this term might be more correctly computed, I have assumed it to have varied as the tangent of the dip, which is no doubt approximately true.

The results of the observations which have been thus severally described are contained in the general table No. XII. at the close of this memoir, arranged in zones of latitude, and in the order of their respective longitudes. This table also contains the correction of each result to the mean epoch of January 1840. The original manuscripts of the unpublished portion of the observations from which these results are derived, together with tabular abstracts containing the details of the corrections applied for the ship's iron, will be deposited in the Hydrographic Office.

The subjoined Table, No. VIII., contains the particulars of the groups into which the results have been formed. The mean declinations at the points of intersection, shown in the final column of the table, constitute the elements from which the declination lines in the map are derived; the lines having been drawn in accordance with them, with only such slight deviations as were indispensable to preserve an interconformity between the lines in a few instances where it was obvious that the elements themselves were slightly discordant with each other.

* Interpolated.

Table VIII.—Elements of the Declination Lines.

Intersections.		Observations employed		Number of additional observations.	Total number of observations.	Mean declination at the point of intersection.
Lat.	Long.	Between the latitudes of	Between the longitudes of			
°	°	°	°			° ′
62·5	285·0	60·0 and 65·0	280·0 and 290·0	...	7	55 17
62·5	290·0	60·0 and 65·0	280·0 and 300·0	...	12	56 48
60·0	290·0	50·0 and 70·0	285·0 and 295·0	...	8	49 07
60·0	295·0	58·5 and 62·5	290·0 and 300·0	...	5	52 20
60·0	355·0	58·0 and 62·0	350·0 and 0·0	...	12	29 01
57·5	310·0	54·0 and 61·0	302·5 and 317·5	...	6	46 52
57·5	315·0	55·0 and 60·0	305·0 and 325·0	...	7	45 22
57·5	320·0	55·0 and 60·0	305·0 and 335·0	...	10	43 38
57·5	325·0	55·0 and 60·0	315·0 and 335·0	1	8	42 05
57·5	330·0	55·0 and 60·0	320·0 and 340·0	...	10	39 55
57·5	335·0	56·0 and 59·0	320·0 and 350·0	...	10	37 29
57·5	340·0	55·0 and 60·0	325·0 and 355·0	1	16	34 59
57·5	345·0	55·0 and 60·0	336·0 and 354·0	...	10	32 35
57·5	350·0	55·0 and 60·0	345·0 and 355·0	...	12	30 20
57·5	353·0	55·0 and 60·0	352·5 and 357·5	...	12	27 56
57·5	357·5	54·0 and 61·0	355·0 and 0·0	...	13	26 58
55·0	300·0	49·0 and 61·0	297·5 and 302·5	4	11	40 48
55·0	305·0	50·0 and 60·0	302·5 and 307·5	2	11	41 37
55·0	310·0	50·0 and 60·0	303·0 and 317·0	1	12	41 42
55·0	315·0	50·0 and 60·0	305·0 and 325·0	2	12	41 54
55·0	320·0	50·0 and 60·0	310·0 and 330·0	...	12	41 14
55·0	325·0	50·0 and 60·0	320·0 and 330·0	...	7	39 50
55·0	330·0	50·0 and 60·0	320·0 and 340·0	...	13	37 56
55·0	335·0	50·0 and 60·0	325·0 and 345·0	2	13	35 42
55·0	340·0	50·0 and 60·0	330·0 and 350·0	1	11	33 51
55·0	345·0	50·0 and 60·0	339·0 and 351·0	1	7	31 45
55·0	350·0	50·0 and 60·0	345·0 and 355·0	1	12	29 33
55·0	355·0	52·5 and 57·5	350·0 and 0·0	4	24	27 17
55·0	0·0	52·5 and 57·5	357·5 and 2·5	3	12	24 54
52·5	350·0	50·0 and 55·0	347·5 and 352·5	...	8	28 41
52·5	355·0	50·0 and 55·0	352·5 and 357·5	1	8	26 15
52·5	0·0	50·0 and 55·0	357·5 and 2·5	...	12	23 50
50·0	280·0	48·0 and 52·0	279·0 and 281·0	...	4	9 01
50·0	295·0	49·0 and 51·0	292·5 and 297·5	2	13	25 09
50·0	300·0	47·5 and 52·5	297·5 and 302·5	...	11	29 49
50·0	305·0	45·0 and 55·0	302·5 and 307·5	1	11	32 45
50·0	325·0	47·0 and 53·0	319·0 and 331·0	1	8	34 32
50·0	330.0	46·0 and 54·0	325·0 and 335·0	1	8	33 53
50·0	335·0	42·5 and 57·5	330·0 and 340·0	2	23	31 52
50·0	340·0	42·5 and 57·5	335·0 and 345·0	2	24	30 21
50·0	345·0	42·5 and 57·5	340·0 and 350·0	2	21	28 52
50·0	350·0	47·5 and 52·5	345·0 and 355·0	2	15	27 14
50·0	355·0	45·0 and 55·0	352·5 and 357·5	...	13	25 22
47·5	290·0	46·5 and 48·5	285·5 and 291·5	1	18	16 10
47·5	295·0	45·0 and 50·0	292·5 and 297·5	...	28	20 50
47·5	300·0	45·0 and 50·0	297·5 and 302·5	...	12	25 09
47·5	305·0	45·0 and 50·0	300·0 and 310·0	1	7	28 24
47·5	325·0	42·5 and 52·5	322·5 and 327·5	...	9	31 41
47·5	330·0	45·0 and 50·0	325·0 and 335·0	2	7	31 02
47·5	335·0	45·0 and 50·0	330·0 and 340·0	...	12	29 44
47·5	340·0	45·0 and 50·0	335·0 and 345·0	2	16	29 14
47·5	345·0	45·0 and 50·0	340·0 and 350·0	1	11	27 50
47·5	350·0	45·0 and 50·0	345·0 and 355·0	1	14	26 11
47·5	355·0	45·0 and 50·0	350·0 and 0·0	2	13	24 34
45·0	285·0	43·5 and 46·5	283·0 and 287·0	2	15	7 54
45·0	290·0	40·0 and 50·0	289·0 and 291·0	2	27	13 08

TABLE VIII. (Continued.)

Intersections.		Observations employed		Number of additional observations.	Total number of observations.	Mean Declination at the point of intersection.
Lat.	Long.	Between the Latitudes of	Between the Longitudes of			
°	°	°	°			° ′
45·0	295·0	42·5 and 47·5	292·5 and 297·5	...	14	17 34
45·0	300·0	42·5 and 47·5	297·5 and 302·5	1	7	20 55
45·0	305·0	40·0 and 50·0	300·0 and 310·0	...	9	24 05
45·0	310·0	40·0 and 50·0	305·0 and 315·0	...	8	26 16
45·0	320·0	43·0 and 47·0	315·0 and 325·0	1	10	28 23
45·0	325·0	42·5 and 47·5	320·0 and 330·0	1	10	29 04
45·0	330·0	42·5 and 47·5	325·0 and 335·0	1	10	28 29
45·0	335·0	40·0 and 50·0	330·0 and 340·0	2	21	27 40
45·0	340·0	40·0 and 50·0	335·0 and 345·0	...	20	27 08
45·0	345·0	40·0 and 50·0	342·5 and 347·5	1	11	26 18
42·5	285·0	39·0 and 46·0	284·0 and 286·0	3	18	5 36
42·5	290·0	40·0 and 45·0	288·0 and 292·0	2	18	9 54
42·5	295·0	39·0 and 46·0	290·0 and 300·0	...	15	14 12
42·5	300·0	39·0 and 46·0	290·0 and 310·0	...	20	17 12
42·5	315·0	40·0 and 45·0	310·0 and 320·0	...	10	24 20
42·5	320·0	40·0 and 45·0	315·0 and 325·0	...	14	25 54
42·5	325·0	40·0 and 45·0	320·0 and 330·0	...	14	26 47
42·5	330·0	40·0 and 45·0	325·0 and 335·0	2	11	26 08
42·5	335·0	40·0 and 45·0	330·0 and 340·0	2	9	25 49
40·0	285·0	37·5 and 42·5	282·5 and 287·5	...	15	4 16
40·0	290·0	37·5 and 42·5	287·5 and 292·5	...	11	7 34
40·0	320·0	35·0 and 45·0	315·0 and 325·0	...	22	22 57
40·0	325·0	35·0 and 45·0	322·5 and 327·5	...	19	24 03
40·0	330·0	35·0 and 45·0	325·0 and 335·0	...	26	24 37
40·0	335·0	35·0 and 45·0	330·0 and 340·0	1	20	24 37
40·0	340·0	37·0 and 43·0	335·0 and 345·0	2	8	24 03
40·0	345·0	35·0 and 45·0	340·0 and 350·0	1	11	23 37
40·0	360·0	35·0 and 45·0	355·0 and 5·0	1	18	20 10
37·5	330·0	35·0 and 40·0	325·0 and 335·0	...	18	23 25
37·5	335·0	35·0 and 40·0	330·0 and 340·0	2	14	23 25
35·0	285·0	30·0 and 40·0	280·0 and 290·0	...	15	1 23
35·0	320·0	32·5 and 37·5	317·5 and 322·5	...	10	18 58
35·0	325·0	30·0 and 40·0	322·5 and 327·5	4	22	20 24
35·0	345·0	32·5 and 37·5	340·0 and 350·0	...	5	22 45
35·0	350·0	32·5 and 37·5	347·5 and 352·5	...	7	21 50
35·0	355·0	32·5 and 37·5	350·0 and 360·0	...	12	20 23
30·0	280·0	25·0 and 35·0	277·5 and 282·5	...	5	− 3 58
30·0	320·0	27·5 and 32·5	315·0 and 325·0	...	21	16 01
30·0	325·0	25·0 and 35·0	322·5 and 327·5	1	20	17 54
30·0	345·0	25·0 and 35·0	340·0 and 350·0	...	20	22 00
25·0	285·0	20·0 and 30·0	280·0 and 290·0	...	10	− 2 36
25·0	320·0	20·0 and 30·0	315·0 and 325·0	...	21	12 38
25·0	325·0	20·0 and 30·0	320·0 and 330·0	...	24	14 59
25·0	330·0	22·5 and 27·5	325·0 and 335·0	3	14	16 51
25·0	340·0	22·5 and 27·5	337·5 and 342·5	1	12	20 02
25·0	342·5	20·0 and 30·0	340·0 and 345·0	...	22	20 07
22·5	340·0	20·0 and 25·0	338·5 and 341·5	...	14	19 36
20·0	285·0	15·0 and 25·0	280·0 and 290·0	...	11	− 3 29
20·0	290·0	17·5 and 22·5	280·0 and 300·0	...	13	− 2 08
20·0	320·0	15·0 and 25·0	317·5 and 322·5	...	9	10 27
20·0	325·0	15·0 and 25·0	320·0 and 330·0	...	10	12 48
20·0	330·0	15·0 and 25·0	325·0 and 335·0	...	15	15 04
20·0	335·0	17·5 and 22·5	330·0 and 340·0	...	14	17 27
20·0	340·0	17·0 and 23·0	337·5 and 342·5	...	14	19 15
15·0	300·0	12·5 and 17·5	297·5 and 302·5	...	4	− 0 55
15·0	325·0	10·0 and 20·0	320·0 and 330·0	...	11	11 32

Table VIII. (Continued.)

Intersections.		Observations employed		Number of additional observations.	Total number of observations.	Mean Declination at the point of intersection.
Lat.	Long.	Between the Latitudes of	Between the Longitudes of			
°	°	° and °	° and °			° ′
15·0	330·0	12·5 and 17·5	325·0 and 335·0	...	15	13 51
15·0	335·0	12·5 and 17·5	330·0 and 340·0	...	23	16 05
15·0	340·0	10·0 and 20·0	337·5 and 342·5	3	14	18 15
10·0	330·0	5·0 and 15·0	326·0 and 334·0	...	15	12 53
10·0	335·0	7·5 and 12·5	332·5 and 337·5	...	15	15 02
10·0	340·0	7·5 and 12·5	337·5 and 342·5	1	9	17 11
10·0	345·0	7·5 and 12·5	342·5 and 347·5	1	10	18 57
5·0	300·0	0·0 and 10·0	296·0 and 304·0	...	10	− 3 56
5·0	330·0	2·5 and 7·5	327·5 and 332·5	1	8	11 57
5·0	335·0	2·5 and 7·5	332·5 and 337·5	...	12	14 20
5·0	340·0	2·5 and 7·5	337·5 and 342·5	3	15	16 21
5·0	345·0	0·0 and 10·0	340·0 and 350·0	...	17	18 21
5·0	350·0	2·5 and 7·5	347·5 and 352·5	...	5	19 34
5·0	355·0	2·5 and 7·5	350·0 and 360·0	2	10	20 06
5·0	0·0	2·5 and 7·5	355·0 and 5·0	1	12	20 11
5·0	5·0	0·0 and 10·0	0·0 and 10·0	...	12	19 58
0·0	330·0	+ 2·5 and − 2·5	327·5 and 332·5	1	16	11 01
0·0	335·0	+ 3·0 and − 3·0	331·0 and 339·0	1	14	14 12
0·0	340·0	+ 3·0 and − 3·0	335·0 and 345·0	1	19	16 24
− 2·5	320·0	0·0 and − 5·0	312·5 and 327·5	...	6	4 58
− 5·0	325·0	0·0 and −10·0	322·0 and 328·0	2	12	7 36
− 5·0	330·0	− 2·5 and − 7·5	327·5 and 332·5	3	19	10 40
− 5·0	335·0	− 1·0 and − 9·0	332·5 and 337·5	...	7	13 58
− 5·0	340·0	− 1·0 and − 9·0	335·0 and 345·0	1	14	16 12
− 5·0	345·0	0·0 and −10·0	342·5 and 347·5	2	15	18 26
−10·0	325·0	− 7·5 and −12·5	322·5 and 327·5	1	9	7 08
−10·0	327·5	− 7·5 and −12·5	325·0 and 330·0	...	14	8 37
−10·0	330·0	− 7·5 and −12·5	327·5 and 332·5	1	17	10 00
−10·0	340·0	− 5·0 and −15·0	335·0 and 345·0	...	10	15 43
−10·0	345·0	− 7·5 and −12·5	342·5 and 347·5	1	10	18 08
−15·0	322·5	−12·0 and −18·0	321·0 and 324·0	3	30	4 23
−15·0	327·5	−12·0 and −18·0	325·0 and 330·0	1	16	7 31
−15·0	330·0	−10·0 and −20·0	328·0 and 332·0	...	14	8 56
−15·0	345·0	−10·0 and −20·0	342·5 and 347·5	1	11	18 10
−15·0	350·0	−14·0 and −16·0	347·5 and 352·5	...	15	20 38
−15·5	352·5	−13·0 and −17·0	350·0 and 355·0	...	17	21 35
−17·5	355·0	−15·0 and −20·0	352·5 and 357·5	2	19	22 40
−20·0	320·0	−17·0 and −23·0	317·5 and 322·5	2	17	1 53
−20·0	325·0	−17·0 and −23·0	324·0 and 326·0	3	12	4 48
−20·0	330·0	−15·0 and −25·0	327·5 and 332·5	...	12	8 02
−20·0	345·0	−15·0 and −25·0	342·5 and 347·5	1	10	17 15
−20·0	350·0	−15·0 and −25·0	347·5 and 352·5	1	14	20 53
−20·0	355·0	−17·0 and −23·0	350·0 and 0·0	2	13	22 50
−22·5	5·0	−18·0 and −27·0	2·0 and 8·0	...	5	25 28
−25·0	315·0	−20·0 and −30·0	313·0 and 317·0	...	16	− 2 22
−25·0	320·0	−22·5 and −27·5	317·5 and 322·5	1	13	0 57
−25·0	325·0	−22·0 and −28·0	322·0 and 328·0	...	7	3 47
−25·0	330·0	−20·0 and −30·0	325·0 and 335·0	...	13	6 51
−25·0	335·0	−23·0 and −27·0	330·0 and 340·0	1	9	9 53
−25·0	340·0	−20·0 and −30·0	335·0 and 345·0	...	14	13 08
−25·0	345·0	−20·0 and −30·0	341·0 and 349·0	...	13	16 43
−25·0	350·0	−20·0 and −30·0	346·0 and 354·0	...	11	20 25
−25·0	7·5	−20·0 and −30·0	360·0 and 00·0	1	9	26 18
−30·0	300·0	−27·0 and −33·0	297·5 and 302·5	...	4	−12 00
−30·0	315·0	−27·5 and −32·5	310·0 and 320·0	...	12	− 3 26
−30·0	320·0	−25·0 and −35·0	316·0 and 324·0	...	15	− 0 26

TABLE VIII. (Continued.)

Intersections.		Observations employed		Number of additional observations.	Total number of observations.	Mean Declination at the point of intersection.
Lat.	Long.	Between the Latitudes of	Between the Longitudes of			
						° ′
−30·0	335·0	−26·0 and −34·0	330·0 and 340·0	2	10	9 00
−30·0	340·0	−55·0 and −35·0	335·0 and 345·0	...	16	12 13
−30·0	345·0	−25·0 and −35·0	340·0 and 350·0	2	16	15 34
−30·0	350·0	−25·0 and −35·0	345·0 and 355·0	2	12	18 40
−30·0	355·0	−27·5 and −32·5	350·0 and 00·0	2	10	21 34
−30·0	0·0	−28·0 and −32·0	358·0 and 02·0	...	7	23 39
−30·0	10·0	−25·0 and −35·0	5·0 and 15·0	1	18	27 22
−35·0	300·0	−31·0 and −39·0	297·0 and 303·0	...	16	−13 15
−35·0	305·0	−34·0 and −36·0	302·5 and 307·5	1	15	−10 38
−35·0	310·0	−30·0 and −40·0	307·5 and 312·5	...	15	− 7 41
−35·0	325·0	−31·0 and −39·0	320·0 and 330·0	...	6	1 39
−35·0	335·0	−30·0 and −40·0	330·0 and 340·0	2	11	7 44
−35·0	340·0	−30·0 and −40·0	336·0 and 344·0	...	11	10 47
−35·0	350·0	−30·0 and −40·0	343·0 and 357·0	2	13	17 03
−35·0	355·0	−30·0 and −40·0	351·0 and 359·0	2	10	19 51
−35·0	0·0	−30·0 and −40·0	355·0 and 05·0	...	18	22 31
−35·0	5·0	−30·0 and −40·0	0·0 and 10·0	1	10	25 10
−35·0	10·0	−32·0 and −38·0	6·0 and 14·0	2	14	26 50
−35·0	15·0	−30·0 and −40·0	13·0 and 17·0	...	22	27 50
−35·0	17·5	−30·0 and −40·0	16·0 and 19·0	...	16	28 51
−40·0	297·5	−38·0 and −42·0	297·0 and 298·0	2	13	−16 02
−40·0	300·0	−37·0 and −43·0	298·0 and 302·0	2	15	−14 30
−40·0	305·0	−37·0 and −43·0	300·0 and 310·0	...	14	−12 13
−42·5	297·5	−41·0 and 44·0	296·0 and 299·0	2	11	−16 42
−42·5	300·0	−40·0 and 45·0	298·5 and 301·0	2	9	−15 17
−45·0	295·0	−42·5 and −47·5	294·0 and 296·5	1	15	−18 34
−47·5	292·5	−45·0 and −50·0	292·0 and 293·0	2	14	−20 00
−47·5	297·5	−45·0 and −50·0	295·0 and 300·0	3	10	−18 19
−50·0	292·5	−47·0 and −53·0	291·5 and 293·0	...	18	−20 49
−50·0	295·0	−47·5 and −52·5	294·0 and 296·5	3	12	−20 15
−50·0	297·5	−47·5 and −52·5	296·0 and 299·5	1	9	−19 15
−50·0	10·0	−47·0 and −53·0	5·0 and 15·0	...	6	−23 35
−52·5	290·0	−50·0 and −55·0	289·5 and 290·0	4	14	−22 48
−52·5	292·5	−50·0 and −55·0	292·0 and 293·0	2	10	−21 50
−52·5	295·0	−50·0 and −55·0	291·0 and 299·0	...	59	−21 04
−52·5	297·5	−50·0 and −55·0	295·0 and 300·0	...	29	−20 15
−52·5	300·0	−51·0 and −54·0	299·0 and 301·0	...	14	−19 39
−52·5	302·5	−50·0 and −55·0	301·0 and 304·0	...	18	−18 33
−55·0	290·0	−54·0 and −56·0	289·0 and 291·0	1	8	−23 41
−55·0	292·5	−54·0 and −56·0	292·0 and 293·0	2	15	−23 16
−55·0	295·0	−54·0 and −56·0	294·0 and 296·0	1	18	−22 31
−55·0	305·0	−53·0 and −57·0	303·0 and 307·0	...	13	−18 17
−57·5	307·5	−55·0 and −60·0	305·0 and 310·0	...	9	−18 25
−57·5	352·5	−56·0 and −59·0	350·0 and 355·0	...	6	−10 58
−60·0	307·5	−56·0 and −64·0	305·0 and 310·0	...	12	−19 31
−62·5	330·0	−62·0 and −63·0	327·0 and 333·0	...	4	− 5 50
−62·5	335·0	−60·0 and −65·0	332·0 and 338·0	...	6	− 2 32
−62·5	345·0	−60·0 and −65·0	343·0 and 347·0	...	7	4 20
−65·0	302·5	−64·0 and −66·0	301·0 and 304·0	...	18	−23 23
−65·0	305·0	−64·0 and −66·0	304·0 and 306·0	2	16	−21 54
−65·0	317·5	−64·0 and −66·0	316·0 and 319·0	...	6	−14 07
−65·0	350·0	−60·0 and −70·0	348·0 and 352·0	...	8	7 01
−67·5	347·5	−65·0 and −70·0	345·0 and 350·0	...	8	4 17
−70·0	345·0	−69·0 and −71·0	343·0 and 347·0	...	4	2 27

General Table of the Declination in the Atlantic.—It may possibly be found convenient for the purposes of navigation, that the books which contain a compendium of the tables requisite to be used at sea, should include a general table of the magnetic Declination at a certain epoch for a convenient number of geographical positions, with auxiliary tables furnishing the means of readily computing the Declination for intermediate positions, and for other years. The subjoined Tables, Nos. IX. and X., have been formed for the purpose of supplying what has frequently appeared to me a desideratum in this respect. No. IX. is a general table of the Declination in the Atlantic for January 1840, at the intersection of every fifth degree of latitude and longitude between 60° north and 60° south latitude, taken from the maps which accompany this memoir. Should this table be adopted in future editions of any of the very useful compendiums referred to, auxiliary tables may be readily computed and added, containing the factors in longitude and latitude for facilitating the calculation of the Declination corresponding to intermediate geographical positions; whilst by means of Table X. the values of the Declinations in Table IX. may be adapted approximately to any other year for which the Declination may be required. The numbers which it contains are the values of the annual secular change of the Declination, which being multiplied by the interval of years from the date to which the table corresponds (*i. e.* January 1840), observing to prefix the sign + to the interval (in years) if the Declination is required for a subsequent year to 1840, or the sign — if required for an earlier year, will give the correction to be applied for the difference of epoch.

The values of the secular change in Table X. are derived from the comparison of the maps which accompany this memoir with the map of the Declination in 1787, published originally (with the observations on which it was based) in Hansteen's Magnetismus der Erde, and republished in this country by myself in the Report of the British Association for the Advancement of Science in 1835. The table consequently represents the average annual secular change which has taken place in the fifty-three years antecedent to 1840. But it will be remembered that the secular change in any particular locality is by no means a constant quantity; and, although over a large proportion of the area of the Atlantic, there is reason to believe that the annual change is still continuing at a rate which does not materially differ from the average of the last fifty years, yet there are parts, (as for example, in the vicinity of the British Islands, and of the Cape of Good Hope,) where the secular change has latterly been obviously undergoing a considerable alteration. Tables formed as these have been, will therefore require to be reformed from time to time; the general table by fresh observations, and the table of secular change by a comparison of the maps founded on those observations with those now given. The time that may be allowed to elapse before the present tables are thus reformed will probably depend less on the interests of navigation and science, than on the degree of attention with which these interests may be regarded by the authorities of the Admiralty in times to come.

But whenever it may be done, it may be expected that the observations of that period will be much more accordant with each other, and with nature, than those which have been at my disposal; in consequence of the general adoption, that we may reasonably anticipate will then have taken place, of the practice of correcting for the deviation in the pointing of the compass occasioned by the ship's iron, and which the increased employment of iron in the equipment of vessels and the magnitude of the errors occasioned thereby, already render in a great number of instances absolutely indispensable. Those who know, as matter of history, the difficulties with which the first introduction of lunar observations and chronometers had to contend, can confidently look forward to a period when the practice of correcting the errors of the compass shall have become general amongst naval officers at least, if not, as may be hoped, amongst merchant seamen also; especially since in the form in which the corrections are now placed, no other preliminary knowledge is required for this purpose than that of the four first rules in arithmetic, with due attention to the signs by which the errors and corrections are characterised.

TABLE IX.—General Table of the Magnetic Declination for January 1840 in the Atlantic Ocean, at the intersection of every 5° of Latitude and Longitude, between 60° North and 60° South Latitude.

Lat.	Longitudes reckoned East from Greenwich.																				Lat.
	280°	285°	290°	295°	300°	305°	310°	315°	320°	325°	330°	335°	340°	345°	350°	355°	0°	5°	10°	15°	20°	
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
60	35 00†	42 30†	49 10	52 20	52 55	53 05	.....	.....	.....	.....	.....	39 15	36 35	33 55	31 25	29 00	26 20	23 30	20 30	.....	.....	60
55	18 20†	25 00†	31 20†	37 00†	40 45	41 40	41 45	41 50	41 15	39 45	37 55	35 45	33 45	31 35	29 30	27 20	24 55	22 25	.....	.....	.....	55
50	9 00	15 00	20 05	25 10	29 50	32 45	34 00	34 50	34 50	34 30	33 40	31 50	30 25	28 55	27 15	25 20	23 15	21 05	.....	.....	.....	50
45	1 40	8 00	13 10	17 30	21 00	24 05	26 15	27 40	28 35	29 05	28 30	27 45	27 10	26 15	24 55	23 25	21 40	20 00	.....	.....	.....	45
40	− 0 40	4 10	7 40	11 35	14 30	17 10	19 20	21 10	22 55	24 00	24 30	24 25	24 05	23 45	23 00	21 40	20 10	18 40	.....	.....	.....	40
35	− 2 10	1 20	4 30	7 30	10 35	13 00	15 10	17 10	19 00	20 25	21 55	22 35	22 50	22 45	21 55	20 30	19 05	.....	.....	.....	.....	35
30	− 4 00	− 0 55	2 05	4 50	7 15	9 35	11 50	14 00	16 00	17 40	19 10	20 40	21 40	22 00	20 55	19 40	.....	.....	.....	.....	.....	30
25	.....	− 2 35	− 0 30	1 50†	4 25†	6 45†	8 55†	10 50	12 50	15 00	16 50	18 40	20 05	21 00	20 10	19 10	.....	.....	.....	.....	.....	25
20	.....	− 3 35	− 2 10	− 0 35	1 25†	3 55†	6 10†	8 20†	10 35	12 50	15 00	17 25	19 10	19 50†	19 45†	18 55†	.....	.....	.....	.....	.....	20
15	.....	.....	− 3 30	− 2 15	− 0 50	1 15†	3 50†	6 20†	9 00†	11 30	13 50	16 05	18 10	19 20†	19 35†	18 55†	.....	.....	.....	.....	.....	15
10	.....	.....	.....	− 3 40	− 2 25	− 0 50	1 25†	4 15†	7 25†	10 20	12 50	15 00	17 15	18 55	19 30†	19 20†	.....	.....	.....	.....	.....	10
5	.....	.....	.....	.....	− 3 55	− 2 05	− 0 05	2 55	6 00	8 55	11 55	14 20	16 25	18 25	19 35	20 05	20 10	20 00	.....	.....	.....	5
0	.....	.....	.....	.....	.....	− 3 15	− 0 45	1 55	5 00	8 05	11 05	14 00	16 20	18 20	19 40	.....	.....	.....	.....	.....	.....	0
− 5	.....	.....	.....	.....	.....	.....	.....	1 20	4 25	7 35	10 40	13 45	16 10	18 25	20 00	21 05†	21 45†	21 50†	21 35†	.....	.....	− 5
−10	.....	.....	.....	.....	.....	.....	.....	0 30	3 35	6 55	10 00	12 50	15 45	18 15	20 15	21 45	22 40†	23 00†	22 55†	.....	.....	−10
−15	.....	.....	.....	.....	.....	.....	.....	− 0 15	2 45	5 55	9 00	12 00	15 00	18 05	20 35	22 25	23 30†	24 15†	24 10†	.....	.....	−15
−20	.....	.....	.....	.....	.....	.....	.....	− 1 10	1 55	4 50	7 55	11 10	14 10	17 25	20 50	22 40	24 05†	25 10†	25 35†	.....	.....	−20
−25	.....	.....	.....	.....	.....	.....	− 5 05	− 2 15	0 50	3 50	6 50	10 00	13 15	16 40	20 15	22 30	24 10†	25 35†	26 35†	26 40†	.....	−25
−30	.....	.....	.....	.....	−12 00	−9 10	− 6 15	− 3 25	− 0 25	2 45	5 45	9 00	12 00	15 25	18 45	21 30	23 40	25 35	27 10	28 15	.....	−30
−35	.....	.....	.....	.....	−13 15	−10 45	− 7 45	− 4 40	− 1 45	1 30	4 35	7 50	10 45	13 45	17 00	20 00	22 35	25 00	26 50	28 10	.....	−35
−40	.....	.....	.....	−17 00	−14 30	−12 10	− 9 25	− 6 15	− 3 05	0 00	3 10	6 25	9 35	12 30	15 30	18 25	21 15	23 50	26 00	27 40	.....	−40
−45	.....	.....	.....	−18 30	−16 20	−13 45	−11 00	− 8 00†	− 5 00†	− 1 45†	1 25†	4 45†	7 55†	11 00†	14 30†	16 55†	19 50†	22 35†	25 05†	27 10†	.....	−45
−50	.....	.....	−21 30	−20 10	−18 20	−15 50	−12 55†	−10 05†	− 6 50†	− 3 40†	− 0 25†	2 45†	6 00†	9 10†	12 15†	15 10	18 05	21 00	23 40	26 15	.....	−50
−55	.....	.....	−23 45	−22 20	−20 40	−18 20	−15 20†	−12 15†	− 9 00†	− 5 40†	− 2 25†	0 45†	4 00†	7 10†	10 20	13 10	16 10	19 10	22 05	24 55	.....	−55
−60	.....	.....	.....	.....	−22 45	−20 30	−17 50	−14 20	−11 10	− 8 00	− 4 50	− 1 25	1 55	5 00	8 15	11 20	14 25	17 25	20 25	23 10	26 00	−60
−65	.....	.....	.....	.....	−24 40	−21 50	−18 55	−15 40	−12 35	− 9 25	− 6 15	− 3 00	0 20	3 40	6 50	9 40	12 40	15 35	18 30	21 25	.....	−65
−70	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	− 0 45	2 15	5 05	.....	.....	.....	.....	.....	.....	−70

The Declinations marked thus † are interpolated in the absence of observations. East Declination is characterised by the sign −. Where no sign is prefixed the Declination is West.

TABLE X.—Annual Secular Change in the Magnetic Declination, on the average of fifty-three years antecedent to January 1840, taken to the nearest half-minute. The sign + in this table implies that the secular change in the period referred to was increasing westerly, or decreasing easterly Declination; and the sign − implies the change to have been decreasing westerly, or increasing easterly Declination.

Lat.	Longitudes reckoned East from Greenwich.																			Lat.
	280°	285°	290°	295°	300°	305°	310°	315°	320°	325°	330°	335°	340°	345°	350°	355°	0°	5°	10°	15°	
60°	+2·0	+6·6	+12·3	+14·0	+14·0	+13·3	+12·5	′	′	′	′	+ 4·0	+ 2·6	+ 1·6	+ 0·5	+ 0·4	+1·1	+1·1	+0·5	′	60°
55	−5·7	−2·3	+ 2·6	+ 5·7	+ 9·3	+10·0	+ 9·3	+ 9·4	+ 9·3	+ 8·2	+ 6·5	+ 4·0	+ 3·7	+ 2·3	+ 0·5	0·0	0·0	0·0	.....	.....	55
50	−4·5	−0·6	+ 1·2	+ 5·4	+ 9·2	+11·0	+10·5	+11·0	+11·0	+ 9·5	+ 8·0	+ 6·0	+ 4·0	+ 2·5	+ 2·0	0·0	0·0	0·0	.....	.....	50
45	−4·5	−1·0	+ 3·2	+ 5·0	+ 7·2	+ 9·0	+10·0	+10·2	+ 9·7	+ 8·5	+ 7·0	+ 5·5	+ 4·1	+ 2·7	+ 1·0	0·0	0·0	0·0	.....	.....	45
40	−2·0	0·0	+ 2·2	+ 4·5	+ 6·2	+ 7·0	+ 7·8	+ 8·2	+ 9·0	+ 8·0	+ 6·5	+ 5·0	+ 4·0	+ 3·0	+ 1·5	0·0	0·0	.....	.....	.....	40
35	0·0	+1·5	+ 2·3	+ 3·2	+ 4·5	+ 5·7	+ 6·2	+ 7·0	+ 7·2	+ 7·0	+ 7·5	+ 5·7	+ 5·0	+ 4·0	+ 2·2	+ 0·5	−0·5	.....	.....	.....	35
30	+0·5	+1·5	+ 2·5	+ 3·6	+ 4·0	+ 5·0	+ 5·5	+ 6·0	+ 6·9	+ 6·4	+ 6·6	+ 6·4	+ 5·3	+ 5·0	+ 3·3	+ 2·0	.....	.....	.....	.....	30
25	.....	+2·0	+ 2·0	+ 2·7	+ 4·0	+ 4·8	+ 5·0	+ 5·0	+ 5·5	+ 6·0	+ 6·0	+ 6·0	+ 6·0	+ 5·3	+ 3·6	+ 2·0	.....	.....	.....	.....	25
20	.....	+1·8	+ 2·2	+ 2·2	+ 2·2	+ 3·9	+ 4·1	+ 4·1	+ 4·6	+ 5·5	+ 5·7	+ 6·0	+ 6·0	+ 5·0	+ 4·0	+ 2·0	.....	.....	.....	.....	20
15	.....	.....	+ 2·0	+ 2·0	+ 2·0	+ 2·3	+ 4·0	+ 4·3	+ 5·7	+ 6·0	+ 6·2	+ 6·1	+ 6·2	+ 5·0	+ 4·0	+ 2·8	.....	.....	.....	.....	15
10	.....	.....	.....	+ 2·0	+ 2·0	+ 2·0	+ 3·7	+ 4·2	+ 5·6	+ 6·5	+ 6·5	+ 6·5	+ 6·5	+ 6·0	+ 4·7	+ 4·0	+3·0	.....	.....	.....	10
5	.....	.....	.....	.....	+ 1·5	+ 2·3	+ 2·7	+ 4·8	+ 6·0	+ 7·0	+ 8·0	+ 8·0	+ 7·3	+ 6·7	+ 5·2	+ 4·5	+3·6	+2·0	.....	.....	5
0	.....	.....	.....	.....	.....	+ 2·5	+ 4·4	+ 5·0	+ 6·5	+ 8·0	+ 8·3	+ 9·0	+ 8·3	+ 7·9	+ 5·7	.....	.....	.....	.....	.....	0
− 5	.....	.....	.....	.....	.....	.....	.....	+ 6·6	+ 7·6	+ 9·0	+ 9·2	+10·0	+ 9·5	+ 9·5	+ 7·0	+ 6·0	+5·0	+3·0	+1·8	.....	5
−10	.....	.....	.....	.....	.....	.....	.....	+ 7·0	+ 8·0	+ 9·8	+10·8	+10·2	+10·2	+ 9·5	+ 8·0	+ 7·0	+6·0	+3·5	+2·0	.....	−10
−15	.....	.....	.....	.....	.....	.....	.....	+ 8·0	+ 9·0	+ 9·5	+10·2	+10·8	+11·0	+10·3	+ 9·3	+ 8·5	+7·0	+5·0	+3·5	.....	−15
−20	.....	.....	.....	.....	.....	.....	.....	+ 8·0	+ 9·2	+ 9·8	+10·5	+11·3	+10·8	+11·0	+11·0	+10·0	+8·0	+6·5	+5·0	.....	−20
−25	.....	.....	.....	.....	.....	.....	+ 7·0	+ 9·0	+ 9·5	+10·5	+10·5	+11·3	+11·0	+11·3	+11·5	+10·8	+9·0	+8·0	+6·0	.....	−25
−30	.....	.....	.....	.....	+ 3·0	+ 5·0	+ 7·0	+ 8·5	+10·0	+11·0	+10·7	+10·7	+10·7	+11·3	+11·4	+10·7	+9·8	+8·5	+7·6	+6·3	−30
−35	.....	.....	.....	.....	+ 3·4	+ 5·5	+ 7·0	+ 8·8	+ 9·3	+10·2	+11·4	+11·5	+11·4	+10·5	+10·4	+11·0	+9·0	+8·5	+8·0	+6·4	−35
−40	.....	.....	.....	+ 1·5	+ 4·0	+ 5·5	+ 6·7	+ 8·0	+ 9·3	+10·2	+11·0	+11·0	+11·0	+10·5	+10·0	+10·0	+9·3	+9·0	+8·3	+7·3	−40
−45	.....	.....	.....	+ 2·3	+ 4·0	+ 5·5	+ 6·4	+ 7·5	+ 8·5	+ 9·5	+ 9·5	+10·8	+10·0	+10·0	+10·0	+10·0	+9·6	+9·0	+8·5	+8·0	−45
−50	.....	.....	+ 1·0	+ 2·5	+ 4·0	+ 4·8	+ 5·7	+ 6·0	+ 7·3	+ 8·3	+ 9·0	+ 9·5	+ 9·5	+ 9·7	+ 9·8	+ 9·5	+9·0	+9·0	+9·0	+9·5	−50
−55	.....	.....	+ 1·5	+ 3·0	+ 3·0	+ 3·4	+ 4·0	+ 4·5	+ 5·5	+ 7·0	+ 8·0	+ 9·0	+ 9·0	+ 9·0	+ 9·2	+ 9·2	+9·2	+9·2	+9·3	+9·3	−55
−60	.....	.....	.....	.....	+ 1·5	+ 1·1	+ 1·1	+ 2·4	+ 3·2	+ 4·5	+ 5·5	+ 6·5	+ 7·3	+ 8·7	+ 9·0	+ 9·0	+9·0	+9·0	+9·0	+9·0	−60

Comparison with M. Gauss's Theory.—As many persons may be desirous of seeing the result of a comparison of the Declinations computed by M. Gauss's general theory, with those derived from observation over a field of considerable extent, I have subjoined in Table XI. in degrees and decimals of a degree, the differences of Declination at the intersections of every five degrees of latitude and longitude. The sign − signifies that the theoretical Declinations are more easterly (i. e. greater east or less west Declination) than the observed; and the sign + that the theoretical are more westerly (i. e. greater west or less east Declination) than the observed.

It must be remembered that the coefficients of M. Gauss's theory in their present numerical values do not profess to be more than a first approximation; that they rest on maps of the phenomena drawn indeed from observation, but in which care was not always taken to use only observations of a definite epoch; that the points of the globe in which the elements of the theory rest upon the observed phenomena are only eighty-four points on the whole surface of the globe, viz. twelve points on seven parallels; no point being taken in a more southern parallel than 20° south latitude; and lastly, that the coefficients are limited to terms of the fourth order.

On the other hand, it will be remembered that the Declination is the easiest, and has been by far the most frequently observed, of the three magnetic elements; that from a very early period maps of the Declination, particularly in the Atlantic, and professing to be adapted to definite epochs, have been in much request on account of their use in navigation; and that consequently it might naturally be expected that the differences between the theory and observation should be *less* in the comparison here instituted, than might be the case in parts of the globe where the elements of the theory have had a less direct, or a less satisfactory derivation.

The differences of greatest amount which appear in this comparison are those over the north-west portion of the Atlantic, amounting to from five to nearly eight degrees generally between the meridian of Newfoundland and the United States, (meridians of 287° to 307°, or 53° to 73° west longitude), in the well-traversed parallels from 45° to 50° N.; and increasing to 18° and upwards in the latitude of 60° in the vicinity of Hudson's Strait, where the correct value of the declination has been well known for several years by the observations of the different British expeditions of discovery. In the southern Atlantic, where, as already remarked, the data of observation on which the theoretical coefficients are based have not been taken from a higher latitude than 20° S., there appears a tendency to systematic differences; in excess (or too small easterly declinations) on the west side of the Atlantic, and in defect (or too small westerly declinations) on the east side of the Atlantic.

A discrepancy deserving of notice in the theoretical lines (i. e in the lines of magnetic Declination as they may be drawn from calculation with the present numerical elements of M. Gauss's theory), is in the value of the remarkable isogonic line, the

Table XI.—Comparison with M. Gauss's Theory.

The sign − signifies that the theoretical Declinations are more easterly (or less westerly) than the observed; and the sign + that they are more westerly (or less easterly) than the observed Declinations.

Lat.	Longitudes reckoned East from Greenwich.																			Lat.
	280°	285°	290°	295°	300°	305°	310°	315°	320°	325°	330°	335°	340°	345°	350°	355°	0°	5°	10°	15°	
60°	−18°8	−18°3	−18°9	−16°0	−12°0	−10°5	.....	.....	.....	.....	.....	.....	.....	.....	+6°7	+6°3	−0°2	−0°2	−0°1	.....	60°
55	−10·7	−10·8	−10·5	−11·4	−10·3	− 8·5	−5·8	−4·9	−3·4	−2·2	−0·7	+0·2	+1·0	+1·2	+1·3	+1·0	+1·0	+0·7	.....	.....	55
50	− 6·2	− 7·3	− 6·9	− 7·6	− 7·7	− 7·4	−5·4	−4·5	−2·7	−1·8	−0·5	+0·8	+1·7	+1·8	+2·0	+2·0	+2·1	+1·9	.....	.....	50
45	− 1·8	− 4·0	− 5·6	− 5·7	− 5·2	− 5·0	−3·9	−3·1	−1·7	−1·0	+0·7	+1·6	+2·3	+2·5	+3·0	+3·0	+3·2	+2·7	.....	.....	45
40	− 1·4	− 3·0	− 3·3	− 3·9	− 3·5	− 3·0	−2·1	−1·4	−0·6	−0·1	+1·1	+1·8	+2·9	+3·0	+3·5	+3·7	+4·2	+3·9	.....	.....	40
35	− 1·2	− 2·1	− 2·7	− 2·8	− 3·1	− 2·6	−1·9	−1·3	−0·5	−0·1	+0·4	+0·9	+1·7	+2·1	+3·2	+3·9	+4·7	.....	.....	.....	35
30	− 0·3	− 1·3	− 2·1	− 2·4	− 2·4	− 2·1	−1·7	−1·2	−0·7	−0·3	+0·3	+0·3	+0·8	+1·1	+2·8	+3·8	.....	.....	.....	.....	30
25	.....	− 0·9	− 1·0	− 1·2	− 1·6	− 1·5	−1·3	−0·7	−0·2	−0·1	+0·3	+0·2	+0·5	+0·6	+2·4	+3·5	.....	.....	.....	.....	25
20	.....	− 0·6	− 0·5	− 0·1	− 0·2	− 0·5	−0·5	−0·2	−0·1	0·0	+0·1	−0·3	−0·2	+0·5	+1·8	+3·1	.....	.....	.....	.....	20
15	.....	.....	− 0·1	+ 0·4	+ 0·7	+ 0·7	+0·3	+0·1	−0·2	−0·4	−0·4	−0·5	−0·5	−0·2	+1·1	+2·5	.....	.....	.....	.....	15
10	.....	.....	.....	+ 0·8	+ 1·2	+ 1·6	+1·4	+0·6	−0·1	−0·7	−0·7	−0·7	−0·7	−0·7	+0·5	+1·6	.....	.....	.....	.....	10
5	.....	.....	.....	.....	+ 1·6	+ 1·8	+1·7	+1·0	+0·2	−0·4	−1·0	−1·1	−0·9	−1·0	−0·2	+0·5	+1·7	+2·2	.....	.....	5
0	.....	.....	.....	.....	.....	+ 1·9	+1·3	+0·8	0·0	−0·6	−1·2	−1·7	−1·6	−1·4	−0·8	.....	.....	.....	.....	.....	0
− 5	.....	.....	.....	.....	.....	.....	.....	+0·4	−0·4	−1·1	−1·7	−2·3	−2·2	−2·2	−1·6	−1·0	+0·1	+0·9	+2·0	.....	− 5
−10	.....	.....	.....	.....	.....	.....	.....	+0·3	−0·6	−1·4	−1·9	−2·2	−2·5	−2·6	−2·2	−1·8	−0·8	0·0	+1·3	.....	−10
−15	.....	.....	.....	.....	.....	.....	.....	0·0	−0·7	−1·3	−1·8	−2·2	−2·5	−3·1	−3·0	−2·7	−1·7	−1·0	+0·5	.....	−15
−20	.....	.....	.....	.....	.....	.....	.....	−0·1	−0·9	−1·2	−1·7	−2·2	−2·5	−3·1	−3·8	−3·6	−2·4	−1·8	−0·5	.....	−20
−25	.....	.....	.....	.....	.....	.....	+0·3	−0·2	−0·9	−1·2	−1·7	−2·1	−2·4	−3·1	−4·0	−3·7	−2·9	−2·4	−1·4	−0·4	−25
−30	.....	.....	.....	.....	+ 2·2	+ 1·3	+0·2	−0·3	−0·9	−1·4	−1·8	−2·2	−2·3	−2·9	−3·4	−3·5	−3·0	−2·8	−2·2	−1·9	−30
−35	.....	.....	.....	.....	+ 2·1	+ 1·5	+0·4	−0·2	−0·9	−1·5	−2·0	−2·3	−2·3	−2·4	−2·8	−3·0	−2·9	−3·0	−2·5	−2·2	−35
−40	.....	.....	.....	+ 3·0	+ 1·9	+ 1·5	+0·7	−0·1	−0·9	−1·3	−1·8	−2·1	−2·4	−2·4	−2·5	−2·7	−2·7	−2·8	−2·5	−2·3	−40
−45	.....	.....	.....	+ 2·9	+ 2·3	+ 1·7	+0·9	+0·3	−0·3	−0·9	−1·3	−1·8	−2·1	−2·4	−2·9	−2·4	−2·5	−2·7	−2·7	−2·7	−45
−50	.....	.....	+ 2·7	+ 3·0	+ 2·8	+ 2·4	+1·5	+1·1	+0·3	−0·2	−0·8	−1·1	−1·5	−1·7	−1·9	−1·8	−1·9	−2·3	−2·3	−2·6	−50
−55	.....	.....	+ 3·1	+ 3·5	+ 3·3	+ 3·4	+2·6	+2·0	+1·2	+0·6	−0·1	−0·2	−0·6	−0·8	−1·1	−1·1	−1·7	−1·4	−1·7	−2·0	−55
−60	.....	.....	.....	.....	+ 4·1	+ 4·2	+3·8	+2·9	+2·3	+1·9	+1·5	+1·0	+0·6	+0·4	+0·1	−0·1	−0·2	−0·4	−0·5	−0·7	−60

branches of which form the limits of the four great systems of isogonic lines, viz. of the four great systems which prevail respectively in the N.W., N.E., S.W. and S.E. directions, and have one isogonic line common to them all, the branches of which meet at a common point of junction or intersection near the west coast of Africa, and not far from the terrestrial equator. The theoretical value of this line is 22° 13′ W.; whereas its true value is certainly not more than between 19° and 20°, and it appears to have been in the year 1840 nearly midway between those values. Had the theoretical value been in defect instead of in excess, the difference might have been ascribed to an effect of secular change; in which case M. Gauss's map might be supposed to represent an earlier state of the phenomena than that of the year 1840. But the fact is otherwise; the theoretical value of the line in question is in excess, although its actual value has been progressively increasing since the earliest record of the phenomena, and was greater in 1848 than in any antecedent year since the phenomena have been observed. The theoretical error is the more remarkable because Mr. Barlow's map for 1833, which was the one employed by M. Gauss for the declination, gives the value of that element correctly at 20° or thereabouts, at the spot where M. Gauss's theoretical line of 22° 13′ cuts the coast of Africa.

The *form* of the lines in Mr. Barlow's map in that quarter of the globe is indeed not correct, since on no part of the surface of the earth do the magnetic lines *fork* in the manner there represented, and which is very different from the *intersection* of lines of equal value forming four branches of one and the same isogonic line, which is the character of the remarkable line now referred to; but the *value* of the declination on that part of the African coast is more correct in Mr. Barlow's map than in M. Gauss's theory, which is partly based upon it. The geographical *position* of the intersection is also given by M. Gauss's theory about 10° of longitude too much to the east. The secular movement of the intersection is to the west, and may be estimated, very roughly, at about 10° in the last half-century.

It is obvious from this comparison that the General Theory will require to have its numerical coefficients reconstructed before it can become available for practical purposes; and that those who desire to take a correct view of the magnetic phenomena, must for the present at least, have recourse to the maps constructed directly from the observations themselves.

Table XII.—Declinations employed in the Map, corrected to the epoch of January 1840.

† in the column of remarks signifies that the Declination has been corrected for the effect of the ship's iron.

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of 65° and 60°.							
63° 18′	280° 41′	1846.	Moore.	58° 21′	−1° 24′	56° 57′	At sea†.
63 13	282 55	1846.	Moore.	55 28	−1 24	54 31	At sea†.
63 15	284 41	1846.	Moore.	58 54	−1 24	57 30	At sea†.
63 19	285 40	1846.	Moore.	60 13	−1 24	58 49	At sea†.
62 57	287 13	1846.	Moore.	58 56	−1 24	57 32	At sea†.
62 47	288 27	1846.	Moore.	58 20	−1 24	56 56	At sea†.
61 54	289 40	1846.	Moore.	54 49	−1 24	53 25	At sea†.
62 13	290 47	1846.	Moore.	59 20	−1 24	57 56	At sea†.
61 00	294 48	1846.	Moore.	55 56	−1 24	54 32	At sea†.
61 34	295 46	1846.	Moore.	58 33	−1 24	57 09	At sea†.
60 49	296 00	1846.	Moore.	56 22	−1 24	54 58	At sea†.
60 58	299 00	1846.	Moore.	55 49	−1 24	54 25	At sea†.
64 08	338 05	1836.	Lottin.	43 14	+0 22	43 36	Reikiavik.
62 00	354 02	1831.	Vidal.	30 50	+0 17	31 07	Thorshavn.
60 09	358 53	1838.	Ross.	27 09	+0 03	27 12	Lerwick.
60 45	359 14	1831.	Vidal.	28 38*	+0 17	28 55	Balta Island.
Between the latitudes of 60° and 50°.							
51 15	279 04	1846.	Moore.	12 40	+0 18	12 58	Moose Factory.
51 18	279 16	1846.	Moore.	10 55	+0 18	11 13	On shore, entrance of Moose Harbour.
51 28	279 26	1846.	Moore.	10 41	+0 18	10 59	At sea†.
51 49	279 28	1846.	Moore.	10 05	+0 18	10 23	At sea†.
50 13	293 35	1831.	Bayfield.	23 34	+0 36	24 10	Bay of Seven Islands.
50 11	293 55	1831.	Bayfield.	24 08	+0 36	24 44	Moisic River.
50 17	295 58	1831.	Bayfield.	25 30	+0 51	26 21	Mingan Harbour.
50 03	296 07	1842.	Lefroy.	26 26	−0 15	26 05	At sea†.
50 14	296 49	1832.	Bayfield.	27 31	+0 50	28 21	Betchewun Harbour.
50 14	297 48	1832.	Bayfield.	28 08	+0 52	29 00	Nabosippe River.
50 11	298 44	1832.	Bayfield.	28 47	+1 00	29 47	Kegashka Bay.
50 11	299 52	1832.	Bayfield.	29 22	+1 00	30 22	Cape Whittle.
50 33	300 43	1833.	Bayfield.	29 33	+0 55	30 28	Little Mecattina.
50 44	300 59	1833.	Bayfield.	30 00	+0 58	31 00	Grand Mecattina.
51 16	301 47	1834.	Bayfield.	31 15	+0 55	32 10	Mistanoque Harbour.
51 27	302 33	1834.	Bayfield.	32 00	+0 56	32 56	Belles Amours Harbour.
51 28	302 45	1834.	Bayfield.	32 30	+0 59	33 29	Bradore Harbour.
51 28	303 03	1833.	Bayfield.	32 26	+1 05	33 41	Forteaw Bay.
59 55	303 20	1846.	Moore.	52 29	−1 24	51 05	At sea†.
51 24	303 26	1833.	Bayfield.	33 30	+1 05	34 35	Green Island in Straits of Bellisle.
51 44	303 34	1835.	Bayfield.	34 30	+0 47	35 17	Red Bay.
52 00	304 09	1835.	Bayfield.	35 30	+0 48	36 18	Chateau Bay.
52 21	304 21	1835.	Bayfield.	37 30	+0 50	38 20	Cape St. Lewis.
58 46	307 00	1846.	Moore.	50 05	−1 21	48 44	At sea†.
56 49	310 26	1846.	Moore.	45 45	−1 15	44 30	At sea†.
57 54	310 34	1846.	Moore.	48 45	−1 15	47 30	At sea†.
57 42	315 57	1846.	Moore.	47 44	−1 15	46 29	At sea†.
54 00	316 24	Sept. 1846.	Moore.	44 00	−1 16	42 44	At sea†.
57 30	319 20	1846.	Moore.	45 28	−1 11	44 17	At sea†.
57 21	321 05	1846.	Moore.	44 33	−1 11	43 22	At sea†.
52 17	321 45	Sept. 1846.	Moore.	39 18	−1 14	38 04	At sea†.

* A mean of 4 stations.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of 60° and 50° (continued).							
57° 05′	324° 10′	1846.	Moore.	43° 16′	−1° 03′	42° 11′	At sea†.
51 47	325 00	Sept. 1846.	Moore.	37 40	−1 08	36 32	At sea†.
51 10	327 09	Sept. 1846.	Moore.	37 43	−1 00	36 43	At sea†.
56 25	327 15	1846.	Moore.	40 19	−0 45	39 34	At sea†.
56 15	329 18	1846.	Moore.	40 14	−0 45	39 29	At sea†.
50 14	330 46	Sept. 1846.	Moore.	35 55	−0 53	35 02	At sea†.
56 16	333 02	1846.	Moore.	38 18	−0 26	37 52	At sea†.
56 00	335 06	1846.	Moore.	36 52	−0 26	36 26	At sea†.
55 41	336 55	1846.	Moore.	36 26	−0 26	36 00	At sea†.
55 53	337 05	1846.	Moore.	35 32	−0 26	35 06	At sea†.
56 09	338 25	1846.	Moore.	36 20	−0 26	35 54	At sea†.
56 19	341 08	1846.	Moore.	34 19	−0 22	33 57	At sea†.
57 43	345 08	1846.	Moore.	32 14	−0 16	31 58	At sea†.
58 40	349 09	1846.	Moore.	31 35	−0 13	31 22	At sea†.
51 56	349 43	Oct. 1838.	Ross.	28 42	−0 06	28 36	Valencia Island.
52 02	350 30	Oct. 1838.	Ross.	28 11	−0 06	28 05	Killarney.
53 48	350 31	Nov. 1838.	Ross.	29 09	−0 06	29 03	Westport.
52 40	351 24	Oct. 1838.	Ross.	28 03	−0 06	27 57	Limerick.
57 49	351 28	Oct. 1831.	Vidal.	30 30	−0 34	29 56	St. Kilda.
51 54	351 32	Oct. 1838.	Ross.	27 44	−0 06	27 38	Cork.
54 14	351 32	Nov. 1838.	Ross.	29 15	−0 06	29 09	Markree.
53 14	352 07	Oct. 1838.	Ross.	28 03	−0 06	27 57	Shannon Harbour.
53 42	352 27	Nov. 1838.	Ross.	28 08	−0 06	28 02	Edgeworthstown.
55 08	352 35	1831.	Vidal.	28 28	−0 06	28 22	Bunerana.
54 59	352 41	Nov. 1838.	Ross.	28 47	−0 06	28 41	Londonderry.
52 15	352 52	Oct. 1838.	Ross.	26 44	−0 06	26 38	Waterford.
54 21	353 21	Nov. 1838.	Ross.	28 08	−0 06	28 02	Armagh.
58 15	353 36	1846.	Otter.	27 40	−0 06	27 34	Stornaway.
53 21	353 45	Oct. 1838.	Ross.	27 35	−0 06	27 29	Dublin.
53 21	353 45	Jan. 1840.	Lloyd.	27 30	0 00	27 30	Dublin Observatory.
59 05	353 53	1831.	Vidal.	29 41	−0 34	29 07	Sulisker.
59 07	354 13	1831.	Vidal.	29 34	−0 34	29 00	Rona.
58 09	354 46	1848.	Otter.	27 59	+0 42	28 41	Loch Inver.
58 23	354 56	1846.	Otter.	27 34	+0 42	28 16	Luxford.
58 15	354 57	1846.	Otter.	27 58	+0 42	28 40	Gowan.
50 09	355 09	1831.	Austin.	25 25	−0 42	24 43	Pendennis Castle.
57 28	355 49	Aug. 1838.	Ross.	27 59	−0 06	27 53	Inverness.
57 58	356 03	Aug. 1838.	Ross.	27 55	−0 06	27 49	Golspie.
58 24	356 55	Aug. 1838.	Ross.	27 41	−0 06	27 35	Wick.
59 00	357 02	Aug. 1838.	Ross.	27 47	−0 06	27 41	Kirkwall.
54 55	357 16	Sept. 1838.	Ross.	26 15	−0 06	26 09	Carlisle.
55 35	357 29	Jan. 1842.	Brisbane.	25 27	+0 10	25 37	Makerstoun Observatory.
58 16	357 49	1846.	Moore.	26 43	+0 42	27 25	At sea†.
57 09	357 55	July 1838.	Ross.	26 41	−0 06	26 35	Aberdeen.
54 58	358 24	Aug. 1838.	Ross.	25 20	−0 06	25 14	Newcastle.
52 57	358 52	May 1838.	Ross.	24 53	−0 06	24 47	Nottingham.
53 57	358 54	April 1838.	Ross.	25 09	−0 06	25 03	York.
54 18	359 34	May 1838.	Ross.	24 32	−0 06	24 26	Scarborough.
54 08	359 46	May 1838.	Ross.	24 39	−0 06	24 33	Bridlington.
51 31	359 38	April 1838.	Ross.	23 59	−0 06	23 53	Busbey.
53 19	0 00	May 1838.	Ross.	24 26	−0 06	24 20	Louth.
51 28	0 00	1841.	Airy.	23 16	+0 07	23 23	Greenwich Observatory.
51 56	1 13	May 1838.	Ross.	23 08	−0 06	23 12	Harwich.
52 56	1 19	May 1838.	Ross.	23 21	−0 06	23 15	Cromer.
51 23	1 23	April 1838.	Ross.	22 54	−0 06	22 48	Margate.
52 28	1 50	May 1838.	Ross.	23 00	−0 06	22 54	Lowestoffe.
50 51	4 22	Jan. 1844.	Quetelet.	21 16	+0 32	21 48	Brussels.
59 54	10 44	Jan. 1840.	Hansteen.	19 50	0 0	19 50	Christiania.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of 50° and 40°.							
43° 40′	280° 38′	Jan. 1840.	Riddell.	1° 27′	0° 00′	1° 27′	Magnetic Observatory, Toronto.
45 36	283 07	May 1843.	Lefroy.	5 11	+0 05	5 16	Fort Portage.
45 29	284 12	May 1843.	Lefroy.	6 58	+0 05	7 03	6 miles below Bytown.
40 08	284 17	May 1846.	U.S. Coast Survey.	4 22	−0 04	4 18	Whitehill.
40 05	284 26	June 1846.	U.S. Coast Survey.	3 13	−0 04	3 09	Fort Delaware.
45 37	284 48	May 1843.	Lefroy.	6 58	+0 05	7 03	Alfred Township.
45 37	285 05	May 1843.	Lefroy.	7 28	+0 05	7 33	Point aux Chênes.
45 36	285 28	May 1843.	Lefroy.	8 41	+0 05	8 46	Carillon.
45 36	285 38	May 1843.	Lefroy.	8 26	+0 05	8 31	On the Ottawa.
40 43	285 59	1844.	Renwick.	6 13	−0 02	6 11	Columbia College.
40 28	286 00	Jan. 1844.	U.S. Coast Survey.	5 51	−0 02	5 49	Sandy Harbour.
45 30	286 25	1842.	Lefroy.	8 58	0 00	8 58	Montreal.
45 32	286 26	1834.	Bayfield.	8 00	0 00	8 00	Montreal.
40 53	286 29	1844.	Renwick.	6 54	−0 02	6 52	Oyster Bay.
45 00	286 39	Oct. 1845.	Boundary Survey.	11 28	0 00	11 28	Rouse's Point.
45 19	286 42	1842.	Lefroy.	11 22	0 00	11 22	St. John's.
46 06	286 59	1830.	Bayfield.	10 30	0 00	10 30	Stone Island.
46 03	287 00	1830.	Bayfield.	11 00	0 00	11 00	Sorel.
46 03	287 00	1842.	Lefroy.	11 23	0 00	11 23	Sorel.
41 15	287 05	Sept. 1845.	U.S. Coast Survey.	6 17	−0 06	6 11	Newhaven.
46 14	287 16	1828.	Bayfield.	11 15	+0 06	11 21	Lake St. Peter.
46 17	287 18	1835.	Bayfield.	10 53	+0 02	10 55	Point du Lac.
44 16	287 23	1829–1830	Graham.	12 26	+0 10	12 36	Montpelier.
46 19	287 24	1842.	Lefroy.	11 58	−0 10	11 57	Three Rivers.
45 53	287 26	1842.	Lefroy.	12 28	−0 01	12 27	Drummondville.
46 25	287 36	1835.	Bayfield.	12 52	+0 02	12 54	Isle Bigôt.
41 06	287 38	1845.	Renwick.	7 14	−0 06	7 08	Sandy Point.
45 00	287 47	Nov. 1845.	Boundary Survey.	11 33	0 00	11 33	Stanstead.
44 02	287 55	Sept. 1830.	Graham.	7 32	+0 10	7 42	Haverhill.
43 56	288 05	Sept. 1830.	Graham.	9 08	+0 10	9 18	Warren.
41 20	288 05	1842.	U.S. Coast Survey.	7 38	−0 06	7 32	Stonington.
46 40	288 06	Aug 1845.	Bayfield.	12 52	+0 02	12 54	Platon Point.
43 49	288 07	Sept. 1830.	Graham.	9 38	+0 10	9 48	West Rumney.
43 45	288 18	Sept. 1830.	Graham.	8 32	+0 10	8 42	Plymouth.
45 01	288 30	Dec. 1845.	Graham.	12 22	0 00	12 22	Canaan Corner.
44 43	288 31	Sept. 1830.	Graham.	7 53	+0 10	8 03	Lake Winninsissiogee.
46 49	288 44	1842.	Lefroy.	14 12	−0 02	14 10	Quebec, Artillery Barracks.
45 15	288 46	May 1845.	Boundary Survey.	12 17	−0 17	12 00	Prospect Hill.
46 49	288 47	1831–1836	Bayfield.	14 14	+0 06	14 20	Quebec, Wolfe's Monument.
45 15	288 47	Oct. 1845.	Boundary Survey.	12 00	−0 18	11 42	Observatory, Connecticut River.
42 23	288 52	1840.	Lowering and Bond.	9 18	0 0	9 18	Observatory, Cambridge, U.S.
45 18	288 55	June 1845.	Boundary Survey.	13 20	−0 17	13 03	Near the Highland Boundary Line.
41 19	288 59	1844.	Renwick.	7 29	−0 05	7 24	Croton Point.
45 20	289 05	June 1845.	Boundary Survey.	13 30	−0 17	13 13	Arnold's River.
41 38	289 05	Aug. 1845.	U.S. Coast Survey.	8 57	−0 08	8 49	Fort Point.
45 26	289 12	July 1845.	Boundary Survey.	13 10	−0 17	12 53	Dead River.
41 28	289 14	Aug. 1846.	U.S. Coast Survey.	9 10	−0 10	9 00	Tarpaulin Town.
43 05	289 15	July 1844.	Boundary Survey.	9 47	−0 14	9 33	Boiling Rock.
45 30	289 16	Oct. 1844.	Boundary Survey.	13 20	−0 17	13 03	Near the Highland Boundary.
45 32	289 18	Sept. 1844.	Boundary Survey.	13 30	−0 16	13 14	Near the Highland Boundary.
45 37	289 23	Sept. 1844.	Boundary Survey.	13 37	−0 16	13 21	Near the Highland Boundary.
41 29	289 24	Aug. 1846.	U.S. Coast Survey.	8 50	−0 10	8 40	Indian Hill.
47 08	289 28	1842.	Lefroy.	14 00	−0 04	13 56	At sea†.
47 04	289 28	1831.	Bayfield.	14 28	+0 19	14 47	Crane Island.
45 42	289 32	Sept. 1844.	Boundary Survey.	13 50	−0 16	13 34	On the Highland Boundary.
47 25	289 34	1831.	Bayfield.	15 17	+0 19	15 36	Isle aux Condres.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.*	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of 50° and 40° (continued).							
45° 39′	289° 36′	Aug. 1844.	Boundary Survey.	14° 07′	−0° 16′	13° 51′	Taschereau's.
47 12	289 38	1831.	Bayfield.	14 49	+0 19	15 08	Stone Pillar.
47 20	289 42	1842.	Lefroy.	14 16	−0 06	14 10	At sea†.
42 03	289 48	Sept. 1835.	Graham.	9 20	+0 11	9 31	Provincetown.
46 25	289 57	Nov. 1844.	Boundary Survey.	15 02	−0 17	14 45	Astron. Station, S.W. branch of the St. John's River.
48 09	290 16	1829.	Bayfield.	17 35	+0 24	17 59	Tadousac.
47 53	290 18	1833.	Bayfield.	17 20	+0 16	17 36	Brandy Pots.
47 51	290 26	1831.	Bayfield.	17 36	+0 19	17 55	River du Loup.
46 57	290 33	Sept. 1844.	Boundary Survey.	16 29	−0 16	16 13	Astron. Station, Big Black River.
48 12	290 51	1829.	U. S. Coast Survey.	17 34	+0 24	17 58	Razade Islands.
48 37	290 53	1831.	Bayfield.	17 36	+0 19	17 55	Port Neuf.
47 14	290 59	Sept. & Oct. 1843.	Boundary Survey.	17 24	−0 18	17 06	Astron. Station, River St. Francis.
47 11	291 04	Oct. 1842.	Boundary Survey.	17 03	−0 13	16 50	Astron. Station, near the mouth of the River St. Francis.
48 25	291 11	1830.	Bayfield.	17 29	+0 24	17 53	Bic Island.
47 16	291 16	Oct. 1842.	Boundary Survey.	17 58	−0 13	17 45	Savage Island.
48 55	291 22	1831.	Bayfield.	18 48	+0 22	19 10	Bersimis Point.
47 17	291 37	Oct. 1842.	Boundary Survey.	17 58	−0 13	17 45	Bourgeois's House.
46 31	291 38	Aug. 1841.	Boundary Survey.	16 43	−0 07	16 36	Mouth of the Massardis River.
47 12	291 46	Aug. 1842.	Boundary Survey.	17 53	−0 12	17 41	Lake Cleveland.
47 19	291 50	Aug. 1843.	Boundary Survey.	18 06	−0 17	17 49	Mouth of Green River.
41 06	292 04	June 1841.	Barnett.	10 08	−0 03	10 05	At sea†.
46 46	292 10	July 1841.	Boundary Survey.	17 27	−0 07	17 20	Near Fort Fairfield.
49 18	292 12	1830.	Bayfield.	19 57	+0 26	20 23	St. Nicholas Harbour.
46 59	292 13	Nov. 1841.	Boundary Survey.	17 43	−0 08	17 35	Peacock Hill.
46 47	292 13	Oct. 1841.	Boundary Survey.	17 28	−0 08	17 20	Aroostook Hill.
46 38	292 13	Oct. 1841.	Boundary Survey.	17 15	−0 08	17 07	Blue Hill.
46 07	292 13	Dec. 1840.	Boundary Survey.	16 09	−0 04	16 05	Parks Hill.
45 57	292 13	Oct. 1840.	Boundary Survey.	16 00*	−0 03	15 57	Astron. Station of the Boundary Commission.
49 04	292 17	1842.	Lefroy.	21 37	−0 08	21 29	At sea†.
49 19	292 37	1830.	Bayfield.	20 13	+0 28	20 41	Port de Monts.
49 38	292 49	1832.	Bayfield.	21 35	+0 24	21 59	Egg Island.
49 06	293 14	1830.	Bayfield.	21 27	+0 28	21 55	Cape Chatte.
41 04	293 19	June 1841.	Barnett.	11 55	−0 03	11 52	At sea†.
49 36	293 21	1842.	Lefroy.	22 30	−0 08	22 22	At sea†.

* "This observation was made at the Astronomical Station on the due north line, 4578 feet north of the Monument marking the source of the River St. Croix. On a Cedar Post 8 inches square erected in 1817 by the Boundary Commissioners under the Treaty of Ghent, at the source of the River St. Croix, is the following inscription:—'Variation 13° 51′·2 by one instrument, and 14° by another,' signed by 'Col. Joseph Bouchette, H.B.M. Surveyor, and John Johnson, U.S. Surveyor, 31st July, 1817.' The Declination in 1840," (as given above,) "is derived from the following observations made by Lieut.-Col. Graham and Lieut. T. J. Lee:—

Oct. 18 and 19, 1840	By Draper's compass No. 4	16° 04′	Mean 16° 00′
	By Stancliffe's compass No. 2	15 58	
	By Draper Nicole's compass No. 1	15 59	
	By Draper Nicole's compass No. 2	16 01	
	By Potter's compass No. 3	16 01	
	By Variation Transit	15 59	

"It appears from the comparisons of the two determinations, one in 1817 and the other in 1840, that the West Declination has increased 2° 04′·5 in 23·22 years; or at an average rate of 5′·3 a year."—Lieut.-Col. Graham, MSS.

TABLE XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of 50° and 40° (continued).							
48° 04′	293° 38′	1839.	Bayfield.	20° 15′	+0° 02′	20° 17′	Dalhousie Island.
48 05	293 52	1838.	Bayfield.	20 23	+0 07	20 30	Carleton Point.
49 15	294 16	1828.	Bayfield.	22 00	+1 03	23 03	Mount Louis River.
41 29	294 22	June 1841.	Barnett.	12 27	−0 05	12 22	At sea†.
48 01	294 25	1838.	Bayfield.	21 21	+0 08	21 29	Paspebiac.
47 06	294 55	1837.	Bayfield.	19 46	+0 15	20 01	Vin Island, Miramichi.
41 28	294 57	June 1841.	Barnett.	13 05	−0 05	13 00	At sea†.
47 49	295 08	1838.	Bayfield.	21 30	+0 09	21 39	Caraquette Island.
46 43	295 12	1839.	Bayfield.	19 50	+0 03	19 53	Richibucto River.
48 12	295 13	1837.	Bayfield.	22 00	+0 15	22 15	Point Macquereaw.
47 45	295 17	1838.	Bayfield.	21 43	+0 09	21 52	Shipfrigan Harbour.
48 01	295 30	1838.	Bayfield.	20 35	+0 09	20 44	Miscow Harbour.
48 50	295 30	1846.	Bayfield.	22 49	−0 37	22 12	Gaspé Basin.
41 28	295 34	June 1841.	Barnett.	13 08	−0 05	13 03	At sea†.
49 48	295 36	1830.	Bayfield.	24 22	+0 52	25 14	Cape Henry, Anticosti.
46 15	295 37	1839.	Bayfield.	19 59	+0 03	20 02	Shediac Island.
46 48	295 57	1845.	Bayfield.	21 10	−0 32	20 38	Cascumpique.
46 10	296 10	1840.	Bayfield.	20 00	−0 03	19 57	Cape Tormentine.
46 24	296 12	1841.	Bayfield.	20 12	−0 09	20 03	Bedeque Harbour.
46 15	296 17	1840.	Bayfield.	20 18	−0 03	20 15	Carleton Head.
46 34	296 17	1845.	Bayfield.	21 00	−0 33	20 27	Richmond Bay.
45 53	296 19	1840.	Bayfield.	19 40	−0 03	19 37	Pugwash Harbour.
45 49	296 34	1840.	Bayfield.	19 50	−0 03	19 47	Wallace Harbour.
46 30	296 40	1845.	Bayfield.	21 41	−0 33	21 08	Cape Turner.
46 14	296 52	1842.	Bayfield.	21 03	−0 15	20 48	Charlotte Town.
45 41	297 20	1841.	Bayfield.	20 19	−0 09	20 10	Pieton Harbour.
46 11	297 27	1843.	Bayfield.	21 58	−0 21	21 37	George Town.
45 38	297 33	1842.	Bayfield.	20 15	−0 15	20 00	Merigomish Harbour.
41 48	297 38	June 1841.	Barnett.	15 54	−0 06	15 48	At sea†.
49 34	298 07	1842.	Lefroy.	27 23	−0 17	27 06	At sea†.
47 14	298 10	1833.	Bayfield.	22 36	+0 45	23 21	Amherst Harbour.
49 08	298 18	1830.	Bayfield.	25 19	+1 07	26 26	East Point (Anticosti).
45 30	299 04	June 1848.	Kelly.	21 05	−0 59	20 06	Isle Madame.
45 35	299 05	Sept. 1848.	Kelly.	22 30	−0 59	21 31	Isle Madame.
46 17	299 37	Aug. 1848.	Kelly.	23 41	−0 59	22 42	St. Ann's Harbour, Cape Breton.
48 05	299 40	1842.	Lefroy.	26 47	−0 18	26 29	At sea†.
49 11	299 47	1842.	Lefroy.	28 16	−0 18	27 58	At sea†.
47 18	300 15	1842.	Lefroy.	25 17	−0 18	24 59	At sea†.
47 53	300 35	1835.	Bayfield.	25 00	+0 32	25 32	Cod Roy Island.
41 34	304 23	June 1841.	Barnett.	18 28	−0 09	18 19	At sea†.
46 13	304 53	1842.	Lefroy.	26 32	−0 23	26 09	At sea†.
45 52	306 49	1842.	Lefroy.	28 04	−0 23	27 41	At sea†.
41 50	307 14	Oct. 1839.	Bérard.	19 00	+0 02	19 02	At sea.
47 34	307 19	1844.	Bayfield.	29 36	−0 43	28 53	St. John's, Newfoundland.
42 54	307 37	June 1841.	Barnett.	22 22	−0 12	22 10	At sea†.
45 12	309 48	1842.	Lefroy.	27 00	−0 22	26 38	At sea†.
43 19	313 35	June 1841.	Barnett.	24 57	−0 12	24 45	At sea†.
43 34	314 42	Aug. 1842.	Lefroy.	26 49	−0 23	26 26	At sea†.
43 06	315 00	Aug. 1842.	Lefroy.	26 15	−0 24	25 51	At sea†.
43 00	316 10	June 1841.	Barnett.	25 43	−0 14	25 29	At sea†.
43 30	317 51	Oct. 1839.	Bérard.	23 55	+0 03	23 58	At sea†.
44 33	318 47	Aug. 1842.	Lefroy.	27 37	−0 24	27 13	At sea†.
43 37	319 18	Aug. 1842.	Lefroy.	28 17	−0 24	27 53	At sea†.
42 20	320 18	Aug. 1842.	Lefroy.	27 07	−0 22	26 45	At sea†.
42 59	321 28	Aug. 1842.	Lefroy.	27 20	−0 22	26 58	At sea†.
43 26	322 00	June 1841.	Barnett.	28 51	−0 12	28 39	At sea†.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of 50° and 40° (continued).							
44° 14′	323° 22′	Aug. 1842.	Lefroy.	28° 32′	−0° 22′	28° 10′	At sea†.
40 32	323 26	Oct. 1837.	Vaillant.	24 52	+0 20	25 12	At sea.
46 09	323 37	Aug. 1842.	Lefroy.	30 38	−0 25	30 13	At sea†.
40 30	323 56	Oct. 1837.	Vaillant.	25 35	+0 20	25 55	At sea.
43 34	324 30	June 1841.	Barnett.	28 22	−0 12	28 10	At sea†.
43 50	324 30	June 1841.	Barnett.	27 12	−0 12	27 00	At sea†.
48 11	324 30	Aug. 1842.	Lefroy.	31 23	−0 25	30 58	At sea†.
42 03	325 11	Oct. 1837.	Vaillant.	24 25	+0 20	24 45	At sea.
40 37	325 13	Oct. 1837.	Vaillant.	26 42	+0 20	27 02	At sea.
47 06	325 40	Aug. 1842.	Lefroy.	32 24	−0 25	31 59	At sea†.
40 55	326 08	Aug. 1830.	Erman.	24 48	+1 16	26 04	At sea.
46 41	326 36	Aug. 1842.	Lefroy.	30 47	−0 22	30 25	At sea†.
41 39	327 19	Aug. 1830.	Erman.	25 16	+1 12	26 28	At sea.
43 26	329 27	Aug. 1830.	Erman.	26 35	+1 08	27 43	At sea.
42 39	329 55	Oct. 1837.	Vaillant.	23 26	+0 15	23 41	At sea.
47 21	330 56	Aug. 1842.	Lefroy.	30 49	−0 18	30 31	At sea†.
44 35	330 57	Aug. 1830.	Erman.	27 36	+1 10	28 46	At sea.
41 37	331 37	1839.	Du Petit-Thouars.	22 07	+0 04	22 11	At sea.
45 41	332 57	Aug. 1830.	Erman.	28 08	+1 02	29 10	At sea.
43 18	333 04	Oct. 1837.	Vaillant.	24 22	+0 13	24 35	At sea.
46 53	334 07	June 1841.	Barnett.	29 40	−0 08	29 32	At sea†.
46 20	335 05	Aug. 1830.	Erman.	28 18	+0 57	29 15	At sea.
47 20	335 09	Aug. 1842.	Lefroy.	31 13	−0 16	30 57	At sea†.
46 49	336 05	June 1841.	Barnett.	30 04	−0 08	29 56	At sea†.
44 03	336 25	Oct. 1837.	Vaillant.	24 20	+0 14	24 34	At sea.
45 45	336 26	Oct. 1839.	Bérard.	25 30	+0 02	25 32	At sea.
47 33	336 56	Aug. 1842.	Lefroy.	31 17	−0 16	31 01	At sea†.
40 35	337 15	1836.	FitzRoy.	25 00	+0 14	25 14	At sea.
46 43	338 23	Oct. 1839.	Bérard.	27 00	+0 01	27 01	At sea.
46 53	338 25	June 1841.	Barnett.	30 51	−0 06	30 45	At sea†.
41 28	338 29	1836.	FitzRoy.	25 38	+0 14	25 52	At sea.
47 03	339 07	Aug. 1830.	Erman.	27 51	+0 45	28 36	At sea.
47 37	339 46	June 1841.	Barnett.	30 30	−0 06	30 24	At sea†.
42 06	339 54	1836.	FitzRoy.	26 00	+0 12	26 12	At sea.
43 14	340 17	June 1839.	Du Petit-Thouars.	22 52	+0 02	22 54	At sea.
48 02	340 55	Aug. 1842.	Lefroy.	30 51	−0 12	30 39	At sea†.
47 55	342 25	June 1841.	Barnett.	28 23	−0 05	28 18	At sea†.
48 11	343 18	June 1841.	Barnett.	29 26	−0 05	29 21	At sea†.
49 16	343 51	Sept. 1846.	Moore.	32 01	−0 20	31 41	At sea†.
44 05	344 05	June 1839.	Du Petit-Thouars.	23 09	+0 02	23 11	At sea.
48 18	344 23	Aug. 1842.	Lefroy.	29 29	−0 08	29 21	At sea†.
47 56	345 03	Aug. 1830.	Erman.	26 19	+0 29	26 48	At sea.
48 34	346 00	June 1841.	Barnett.	28 37	−0 05	28 32	At sea†.
40 15	346 10	1836.	FitzRoy.	24 45	+0 10	24 55	At sea.
41 00	346 30	1836.	FitzRoy.	24 49	+0 10	24 59	At sea.
42 31	347 20	1836.	FitzRoy.	24 18	+0 10	24 28	At sea.
42 37	347 30	1836.	FitzRoy.	23 34	+0 10	23 44	At sea.
43 20	348 00	1836.	FitzRoy.	23 50	+0 10	24 00	At sea.
48 42	348 04	June 1841.	Barnett.	27 22	−0 05	27 17	At sea†.
48 27	348 32	Aug. 1830.	Erman.	26 07	+0 23	26 30	At sea.
48 48	349 28	Aug. 1842.	Lefroy.	27 44	−0 03	27 41	At sea†.
49 25	350 15	Sept. 1846.	Moore.	27 46	0 00	27 46	At sea†.
48 57	350 28	Aug. 1830.	Erman.	25 54	+0 10	26 04	At sea.
46 18	351 54	June 1839.	Du Petit-Thouars.	24 14	0 00	24 14	At sea.
46 38	351 54	Dec. 1842.	Jehenne.	27 10	0 00	27 10	At sea.
49 11	352 22	Aug. 1842.	Lefroy.	26 16	+0 05	26 21	At sea†.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of 50° and 40° (continued).							
47 20	355 14	Aug. 1830.	Erman.	25 10	0 00	25 10	At sea.
47 44	354 16	Aug. 1830.	Erman.	24 35	0 00	24 35	At sea.
48 09	355 02	June 1839.	Du Petit-Thouars.	24 03	0 00	24 03	At sea.
46 59	355 13	Aug. 1830.	Erman.	24 02	0 00	24 02	At sea.
48 23	355 31	Nov. 1837.	Darondean.	24 58	−0 10	24 48	Brest.
49 58	356 27	Aug. 1842.	Lefroy.	25 18	0 00	25 18	At sea†.
40 22	1 56	June 1838.	Bérard.	20 01	0 00	20 01	At sea.
48 50	2 22	Feb. 1838.	Darondean.	21 38	0 00	21 38	Paris Observatory.
40 13	2 26	Aug. 1842.	Bérard.	19 45	0 00	19 45	At sea.
40 24	2 27	June 1838.	Bérard.	21 29	0 00	21 29	At sea.
40 48	2 30	Aug. 1842.	Bérard.	19 00	0 00	19 00	At sea.
41 11	2 39	Aug. 1842.	Bérard.	19 30	0 00	19 30	At sea.
41 26	3 52	Aug. 1842.	Bérard.	19 30	0 00	19 30	At sea.
41 32	4 18	Aug. 1842.	Bérard.	19 00	0 00	19 00	At sea.
42 04	4 48	Aug. 1842.	Bérard.	18 30	0 00	18 30	At sea.
43 05	5 55	Jan. 1836.	Darondean.	19 16	0 00	19 16	Toulon.
46 12	6 09	Jan. 1843.	Plantamour.	18 57	+0 15	19 12	Geneva.
Between the latitudes of 40° and 30°.							
32 41	280 07	May 1841.	Barnett.	− 2 24	−0 05	− 2 29	Charleston.
30 54	280 15	May 1841.	Barnett.	− 3 07	−0 05	− 3 12	At sea†.
31 54	280 29	May 1841.	Barnett.	− 2 45	−0 05	− 2 50	At sea†.
38 56	283 25	June 1845.	U.S. Coast Survey.	+ 2 14	−0 08	+ 2 06	Annapolis.
33 55	283 57	May 1841.	Barnett.	− 1 25	−0 05	− 1 30	At sea†.
39 22	284 30	June 1846.	U.S. Coast Survey.	+ 3 18	−0 08	+ 3 10	Bombay Hook.
39 25	284 40	June 1846.	U.S. Coast Survey.	2 15	−0 08	2 07	
39 58	284 50	May 1846.	U.S. Coast Survey.	3 51	−0 08	3 43	Girard College.
39 10	284 52	June 1846.	U.S. Coast Survey.	2 59	−0 08	2 51	Egg Island.
38 47	284 54	May 1841.	Barnett.	4 42	−0 05	4 37	Cape Henlopen.
39 15	284 59	June 1846.	U.S. Coast Survey.	3 06	−0 05	3 01	Port Norris.
35 08	285 28	May 1841.	Barnett.	1 57	−0 05	1 52	At sea†.
38 00	285 35	May 1841.	Barnett.	3 51	−0 02	3 49	At sea†.
39 31	285 41	Nov. 1846.	U.S. Coast Survey.	4 24	−0 05	4 19	Tuche Island.
38 45	289 09	May 1841.	Barnett.	6 44	−0 07	6 37	At sea†.
39 18	290 20	May 1841.	Barnett.	6 58	−0 07	6 51	At sea†.
39 37	290 30	May 1841.	Barnett.	7 25	−0 07	7 18	At sea†.
39 52	291 20	May 1841.	Barnett.	7 42	−0 07	7 35	At sea†.
32 23	295 09	Aug. 1846.	Barnett.	6 53	−0 39	6 14	Bermuda.
32 23	295 16	May 1837.	Milne.	6 40	+0 15	6 55	Bermuda.
32 18	300 42	Nov. 1842.	Jehenne.	8 46	−0 18	8 28	At sea.
33 53	318 07	Aug. 1830.	Erman.	17 00	+1 26	18 26	At sea.
34 44	318 13	Aug. 1830.	Erman.	17 03	+1 26	18 29	At sea.
33 39	318 32	Aug. 1830.	Erman.	17 00	+1 26	18 26	At sea.
31 36	318 58	June 1839.	Du Petit-Thouars.	16 00	+0 04	16 04	At sea.
32 53	318 58	Aug. 1830.	Erman.	16 28	+1 26	17 54	At sea.
31 56	319 20	June 1839.	Du Petit-Thouars.	15 52	+0 04	15 56	At sea.
35 59	319 32	Aug. 1830.	Erman.	18 02	+1 26	19 28	At sea.
31 48	319 36	Aug. 1830.	Erman.	15 40	+1 26	17 06	At sea.
30 32	319 45	Aug. 1830.	Erman.	15 03	+1 26	16 29	At sea.
34 04	320 12	June 1839.	Du Petit-Thouars.	17 22	+0 04	17 26	At sea.
30 48	320 16	May 1846.	Sulivan.	17 47	−0 58	16 49	At sea†.
32 10	321 05	May 1846.	Sulivan.	18 15	−0 58	17 17	At sea†.
37 28	321 25	Aug. 1830.	Erman.	19 43	+1 26	21 09	At sea.
30 02	321 27	June 1839.	Du Petit-Thouars.	18 30	+0 04	18 34	At sea.
37 05	321 35	Nov. 1842.	Jehenne.	21 02	−0 22	20 40	At sea.
33 46	322 10	May 1846.	Sulivan.	19 15	−0 55	18 20	At sea†.
35 17	322 14	Oct. 1837.	Vaillant.	18 37	+0 20	18 57	At sea.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of 40° and 30° (continued).							
33° 17′	322° 37′	July 1846.	Bérard.	19° 13′	−0° 57′	18° 16′	At sea.
36 18	322 46	Oct. 1837.	Vaillant.	17 33	+0 20	17 53	At sea.
38 43	323 02	Aug. 1830.	Erman.	21 43	+1 20	23 03	At sea.
37 48	323 07	June 1839.	Du Petit-Thouars.	19 57	+0 04	20 01	At sea.
32 11	323 13	July 1846.	Bérard.	18 30	−0 57	17 33	At sea.
33 54	323 14	Oct. 1837.	Vaillant.	18 02	+0 20	18 22	At sea.
32 46	323 41	July 1846.	Bérard.	18 29	−0 55	17 34	At sea.
31 04	324 03	1836.	FitzRoy.	18 28	+0 28	18 56	At sea.
39 15	324 36	Aug. 1830.	Erman.	23 06	+1 16	24 22	At sea.
37 09	324 36	May 1846.	Sulivan.	23 37	−0 52	22 45	At sea†.
30 01	324 39	Oct. 1837.	Vaillant.	18 38	+0 20	18 58	At sea.
32 03	324 55	1836.	FitzRoy.	18 22	+0 28	18 50	At sea.
34 35	325 11	July 1846.	Bérard.	18 34	−0 52	17 40	At sea.
37 40	325 15	May 1846.	Sulivan.	23 50	−0 50	23 00	At sea†.
31 01	325 41	Oct. 1837.	Vaillant.	18 02	+0 19	18 21	At sea.
39 32	325 54	June 1839.	Du Petit-Thouars.	20 55	+0 04	20 59	At sea.
38 10	325 55	May 1846.	Sulivan.	23 21	−0 50	22 31	At sea†.
35 17	326 58	July 1846.	Bérard.	19 49	−0 52	18 57	At sea.
36 38	327 48	July 1846.	Bérard.	20 59	−0 52	20 07	At sea.
35 38	328 28	1836.	FitzRoy.	21 34	+0 26	22 00	At sea.
39 24	328 48	1843–1844	Vidal.	27 30	−0 25	27 05	Flores.
39 41	328 53	1842.	Vidal.	27 30	−0 18	27 12	Corvo.
36 40	330 52	July 1846.	Bérard.	20 42	−0 52	19 50	At sea.
37 15	331 06	1836.	FitzRoy.	22 09	+0 26	22 35	At sea.
39 05	331 56	1843–1844	Vidal.	26 46	−0 25	26 21	Graciosa.
37 49	332 00	1836.	FitzRoy.	24 00	+0 26	24 26	At sea.
38 39	332 47	1836.	FitzRoy.	24 19	+0 26	24 45	Terceira.
38 45	332 52	July 1836.	FitzRoy.	24 21	+0 26	24 47	At sea.
37 44	334 17	May 1831.	Austin.	24 31	+0 54	25 25	St. Michaels.
37 48	334 20	1836.	FitzRoy.	24 15	+0 22	24 37	St. Michaels.
37 46	334 20	1843–1844	Vidal.	25 45	−0 22	25 23	St. Michaels.
36 57	334 55	1843–1844	Vidal.	25 17	−0 22	24 55	Santa Maria.
36 19	339 41	Aug. 1846.	Bérard.	20 51	−0 36	20 15	At sea.
37 05	341 35	Nov. 1842.	Jehenne.	21 02	−0 10	20 52	At sea.
33 00	343 50	1832.	FitzRoy.	23 00	+0 34	23 34	At sea.
37 20	344 30	1836.	FitzRoy.	23 54	+0 14	24 08	At sea.
38 41	345 00	1836.	FitzRoy.	23 35	+0 14	23 49	At sea.
30 02	346 18	Feb. 1836.	Vaillant.	22 24	+0 22	22 46	At sea.
30 41	346 36	Sept. 1842.	Bérard.	22 00	−0 11	21 49	At sea.
31 16	347 32	Sept. 1842.	Bérard.	23 00	−0 11	22 49	At sea.
33 16	348 09	June 1838.	Bérard.	20 01	+0 06	20 07	At sea.
32 19	348 49	Sept. 1842.	Bérard.	22 45	−0 11	22 34	At sea.
33 34	349 06	Feb. 1836.	Vaillant.	24 31	+0 23	24 54	At sea.
33 00	350 05	Sept. 1842.	Bérard.	22 00	−0 08	21 52	At sea.
34 10	351 20	Sept. 1842.	Bérard.	22 00	−0 08	21 52	At sea.
31 57	351 51	June 1838.	Bérard.	20 05	+0 05	20 10	At sea.
35 59	352 14	Feb. 1836.	Vaillant.	22 20	+0 10	22 30	At sea.
35 25	352 16	Aug. 1846.	Bérard.	21 05	−0 15	20 50	At sea.
35 25	353 11	June 1838.	Bérard.	22 13	+0 03	22 16	At sea.
36 11	353 34	Aug. 1846.	Bérard.	20 26	−0 12	20 14	At sea.
35 29	353 47	Aug. 1846.	Bérard.	20 35	−0 12	20 23	At sea.
36 26	356 03	Aug. 1846.	Bérard.	19 15	0 00	19 15	At sea.
35 48	357 00	1842.	Bérard.	18 30	+0 03	18 33	At sea.
36 20	358 52	Aug. 1846.	Bérard.	18 49	+0 10	18 59	At sea.
36 46	358 53	June 1838.	Bérard.	19 47	−0 04	19 43	At sea.
36 28	359 19	Aug. 1846.	Bérard.	19 16	+0 18	19 34	At sea.
36 10	359 40	Aug. 1846.	Bérard.	19 18	+0 18	19 36	At sea.
38 58	1 00	Aug. 1846.	Bérard.	19 48	+0 18	20 06	At sea.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
			Between the latitudes of 30° and 20°.				
37 33	1 15	Aug. 1842.	Bérard.	17 37	+0 07	17 44	At sea.
36 47	3 05	Oct. 1842.	Aime.	18 35	+0 08	18 43	Algiers Magnetic Observatory.
28 22	279 35	May 1841.	Barnett.	— 4 57	−0 05	— 5 02	At sea†.
29 17	280 24	May 1841.	Barnett.	— 4 44	−0 05	— 4 49	At sea†.
25 05	282 39	May 1838.	Milne.	— 3 07	+0 03	— 3 04	Nassau.
20 00	283 57	July 1837.	Milne.	— 3 39	+0 04	— 3 35	St. Jago, Cuba.
21 33	284 15		Milne.	— 4 02	+0 03	— 3 59	San Domingo.
27 55	285 24	Nov. 1842.	Jehenne.	— 2 07	−0 09	— 2 16	At sea.
20 22	285 26	1831.	Austin.	— 3 17	+0 12	— 3 05	Barracon, Cuba.
22 07	285 36	1831.	Austin.	— 4 27	+0 12	— 4 15	Crooked Island.
22 47	285 39	July 1837.	Milne.	— 2 34	+0 05	— 2 29	Crooked Island.
20 14	285 48	1831.	Austin.	— 2 27	+0 12	— 2 15	Cape Maize.
21 26	288 53	Nov. 1845.	Barnett.	— 1 48	−0 12	— 2 00	Turks Island, Bahamas.
28 15	315 50	June 1839.	Du Petit-Thouars.	13 32	+0 04	13 36	At sea.
29 11	316 36	June 1839.	Du Petit-Thouars.	14 16	+0 02	14 18	At sea.
27 51	316 53	June 1839.	Du Petit-Thouars.	13 25	+0 02	13 27	At sea.
26 57	318 08	June 1839.	Du Petit-Thouars.	12 37	+0 02	12 39	At sea.
25 13	319 09	June 1839.	Du Petit-Thouars.	12 30	+0 02	12 32	At sea.
26 32	319 46	May 1846.	Sulivan.	13 17	−0 42	12 35	At sea†.
29 27	319 50	May 1846.	Sulivan.	14 24	−0 42	13 42	At sea†.
24 00	320 08	June 1839.	Du Petit-Thouars.	11 30	+0 03	11 33	At sea.
21 34	320 18	May 1846.	Sulivan.	12 29	−0 42	11 47	At sea†.
20 19	320 45	May 1846.	Sulivan.	11 23	−0 42	10 41	At sea†.
22 34	320 56	June 1839.	Du Petit-Thouars.	11 20	+0 03	11 23	At sea.
28 12	321 08	Aug. 1830.	Erman.	14 33	+1 16	15 49	At sea.
26 23	321 57	Aug. 1830.	Erman.	13 07	+1 03	14 10	At sea.
23 41	322 14	1830.	Erman.	11 50	+0 50	12 40	At sea.
29 15	323 40	1836.	FitzRoy.	17 10	+0 27	17 37	At sea.
22 48	323 55	July 1838.	Bérard.	9 40	+0 08	9 48	At sea.
28 07	324 00	1836.	FitzRoy.	17 06	+0 21	17 27	At sea.
29 52	324 34	July 1846.	Bérard.	17 55	−0 39	17 16	At sea.
21 42	324 35	1830.	Erman.	11 58	+0 47	12 45	At sea.
28 13	324 41	July 1846.	Bérard.	17 30	−0 39	16 51	At sea.
27 17	325 13	July 1846.	Bérard.	17 57	−0 39	17 18	At sea.
29 17	325 32	Oct. 1837.	Vaillant.	17 26	+0 18	17 44	At sea.
25 00	325 41	1836.	FitzRoy.	16 05	+0 21	16 26	At sea.
26 52	325 52	July 1846.	Bérard.	18 30	−0 39	17 51	At sea.
23 41	326 11	1836.	FitzRoy.	15 20	+0 21	15 41	At sea.
25 44	326 34	July 1846.	Bérard.	17 26	−0 39	16 47	At sea.
25 57	327 12	Oct. 1837.	Vaillant.	16 37	+0 15	16 52	At sea.
23 20	327 23	July 1846.	Bérard.	15 19	−0 33	14 46	At sea.
23 02	327 30	July 1838.	Bérard.	10 30	+0 08	10 38	At sea.
21 27	328 42	July 1846.	Bérard.	16 41	+0 33	16 08	At sea.
22 30	329 04	Oct. 1837.	Vaillant.	14 54	+0 12	15 06	At sea.
20 32	330 00	Oct. 1837.	Vaillant.	14 22	+0 12	14 34	At sea.
25 05	330 33	July 1838.	Bérard.	16 44	+0 15	16 59	At sea.
26 12	333 21	July 1838.	Bérard.	17 19	+0 15	17 34	At sea.
20 24	337 11	Sept. 1842.	Bérard.	19 30	−0 15	19 15	At sea.
21 24	338 04	Dec. 1846.	Stanley.	18 14	−0 38	17 36	At sea†.
22 24	338 29	Sept. 1842.	Bérard.	20 00	−0 15	19 45	At sea.
20 18	338 32	1832.	FitzRoy.	18 20	+0 45	19 05	At sea.
20 42	338 39	1832.	FitzRoy.	18 24	+0 45	19 09	At sea.
23 22	339 08	Dec. 1846.	Stanley.	19 41	−0 41	19 00	At sea†.
21 43	339 20	1832.	FitzRoy.	18 30	+0 45	19 15	At sea.
21 10	339 35	Jan. 1837.	Du Petit-Thouars.	18 42	+0 18	19 00	At sea.
22 22	340 04	Nov. 1839.	Ross.	19 25	0 00	19 25	At sea†.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of 30° and 20° (continued).							
23° 09′	340° 13′	1832.	FitzRoy.	18° 47′	+0° 44′	19° 31′	At sea.
22 01	340 16	Feb. 1836.	Vaillant.	20 08	+0 24	20 32	At sea.
21 50	340 28	Jan. 1837.	Du Petit-Thouars.	20 03	+0 16	20 19	At sea.
23 38	340 43	Nov. 1839.	Ross.	19 30	0 00	19 30	At sea†.
23 50	340 51	Nov. 1839.	Ross.	19 12	0 00	19 12	At sea†.
26 17	340 59	Sept. 1842.	Bérard.	21 00	−0 15	20 45	At sea.
23 31	341 10	Jan. 1837.	Du Petit-Thouars.	19 55	+0 16	20 11	At sea.
24 31	341 17	Nov. 1839.	Ross.	20 15	0 00	20 15	At sea†.
24 40	341 18	1832.	FitzRoy.	19 53	+0 41	20 34	At sea.
23 37	341 31	Feb. 1836.	Vaillant.	21 02	+0 21	21 23	At sea.
25 33	341 55	Nov. 1839.	Ross.	21 33	0 00	21 33	At sea†.
25 26	341 58	1832.	FitzRoy.	19 59	+0 41	20 40	At sea.
24 58	342 56	Feb. 1836.	Vaillant.	20 35	+0 21	20 56	At sea.
27 59	343 01	Sept. 1842.	Bérard.	21 00	−0 15	20 45	At sea.
26 59	343 12	1832.	FitzRoy.	20 04	+0 41	20 45	At sea.
28 12	343 40	1832.	FitzRoy.	20 20	+0 41	21 01	At sea.
29 31	343 40	1832.	FitzRoy.	20 44	+0 41	21 25	At sea.
28 26	343 44	Nov. 1839.	Ross.	20 31	0 00	20 31	At sea†.
28 28	343 45	1837.	Vidal.	22 40	+0 10	22 50	Santa Cruz.
26 15	344 06	Feb. 1836.	Vaillant.	22 16	+0 15	22 31	At sea.
27 22	344 38	Feb. 1836.	Vaillant.	21 44	+0 15	21 59	At sea.
29 15	345 16	Sept. 1842.	Bérard.	22 00	−0 10	21 50	At sea.
29 12	346 05	Feb. 1836.	Vaillant.	22 02	+0 15	22 17	At sea.
Between the latitudes of 20° and 10°.							
17 56	283 09	April 1847.	Barnett.	− 3 40	−0 10	− 3 50	Jamaica.
17 56	283 09	Oct. 1837.	Milne.	− 4 18	+0 03	− 4 15	Jamaica.
17 55	283 44	1831.	Austin.	− 5 13	+0 12	− 5 01	Point Morant.
10 25	284 25	Sept. 1837.	Milne.	− 5 41	+0 04	− 5 37	Carthagena.
19 55	284 45	July 1837.	Milne.	− 3 31	+0 05	− 3 26	Cumberland Harbour.
11 15	285 45	Sept. 1837.	Milne.	− 5 29	+0 04	− 5 25	Santa Martha.
19 39	295 51	July 1838.	Bérard.	− 0 01	+0 03	+ 0 02	At sea.
18 14	296 51	1846.	Barnett.	− 0 56	−0 12	− 1 08	Anguilla Island.
17 08	298 08	Nov. 1840.	Milne.	− 0 42	−0 01	− 0 43	Antigua.
17 08	298 08	Jan. 1848.	Barnett.	− 0 46	−0 16	− 1 02	Antigua.
13 05	300 22	Nov. 1839.	Milne.	− 1 13	0 00	− 1 13	Barbadoes.
13 05	300 24	1846.	Schomburgk.	− 1 27	−0 12	− 1 39	Barbadoes.
18 18	321 24	May 1846.	Sulivan.	+11 24	−0 32	+10 52	At sea†.
17 02	321 51	May 1846.	Sulivan.	9 38	−0 32	9 06	At sea†.
19 19	321 51	May 1839.	Du Petit-Thouars.	11 56	+0 02	11 58	At sea.
15 21	322 28	May 1846.	Sulivan.	10 49	−0 35	10 14	At sea†.
16 36	323 27	May 1839.	Du Petit-Thouars.	11 13	+0 02	11 15	At sea.
13 55	325 01	May 1839.	Du Petit-Thouars.	11 34	+0 02	11 36	At sea.
11 58	327 30	May 1839.	Du Petit-Thouars.	11 42	+0 03	11 45	At sea.
16 20	328 52	July 1830.	Erman.	12 36	+0 54	13 30	At sea.
18 57	329 36	July 1830.	Erman.	13 02	+0 50	13 52	At sea.
19 22	329 41	July 1846.	Bérard.	15 08	−0 38	14 30	At sea.
15 13	329 56	July 1830.	Erman.	13 08	+0 57	14 05	At sea.
17 17	330 40	July 1846.	Bérard.	17 16	−0 33	16 43	At sea.
18 31	330 57	Oct. 1837.	Vaillant.	14 04	+0 14	14 18	At sea.
14 01	331 11	July 1830.	Erman.	12 40	+1 01	13 41	At sea.
12 51	331 31	July 1830.	Erman.	12 55	+1 01	13 56	At sea.
11 53	331 43	July 1830.	Erman.	12 56	+1 01	13 57	At sea.
16 39	332 16	Oct. 1837.	Vaillant.	14 20	+0 15	14 35	At sea.
10 36	333 00	July 1830.	Erman.	13 33	+1 01	14 34	At sea.
12 17	333 35	May 1832.	FitzRoy.	13 43	+0 49	14 32	At sea.
14 49	333 41	Oct. 1837.	Vaillant.	14 32	+0 15	14 47	At sea.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
			Between the latitudes of 20° and 10° (continued).				
13 36	334 16	July 1846.	Bérard.	17 04	−0 40	16 24	At sea.
13 02	334 21	Sept. 1842.	Bérard.	13 00	−0 17	12 47	At sea.
13 38	334 26	Sept. 1842.	Bérard.	13 50	−0 17	13 37	At sea.
11 13	334 36	Sept. 1842.	Bérard.	15 00	−0 17	14 47	At sea.
13 20	334 40	May 1832.	FitzRoy.	14 49	+0 49	15 38	At sea.
13 55	334 40	Oct. 1837.	Vaillant.	15 06	+0 15	15 18	At sea.
16 35	334 42	Sept. 1842.	Bérard.	17 00	−0 17	16 47	At sea.
10 00	334 44	Nov. 1839.	Ross.	15 47	0 00	15 47	At sea†.
12 46	335 25	Sept. 1837.	Vaillant.	15 23	+0 14	15 37	At sea.
12 12	335 30	Nov. 1839.	Ross.	16 26	0 00	16 26	At sea†.
15 29	336 08	1832.	FitzRoy.	15 52	+0 49	16 41	At sea.
14 43	336 21	1836.	FitzRoy.	17 02	+0 21	17 23	At sea.
15 17	336 25	1832.	FitzRoy.	15 22	+0 49	16 11	At sea.
10 13	336 28	Jan. 1837.	Du Petit-Thouars.	16 59	+0 18	17 17	At sea.
14 56	336 28	Nov. 1839.	Ross.	16 26	0 00	16 26	At sea†.
14 54	336 30	1831.	FitzRoy.	16 30	+0 55	17 25	Port Praya.
13 36	336 37	July 1846.	Bérard.	17 04	−0 39	16 25	At sea.
15 49	336 40	Jan. 1847.	Stanley.	18 04	−0 42	17 22	At sea†.
11 59	336 47	Sept. 1837.	Vaillant.	16 42	+0 14	16 56	At sea.
12 17	336 48	Jan. 1847.	Stanley.	15 55	−0 42	15 13	At sea†.
17 50	336 50	1832.	FitzRoy.	17 06	+1 00	18 06	At sea.
19 02	336 51	Jan. 1847.	Stanley.	20 35	−0 42	19 53	At sea†.
11 37	337 00	Jan. 1846.	Bérard.	16 12	−0 39	15 33	At sea.
13 16	337 21	Jan. 1837.	Du Petit-Thouars.	17 32	+0 18	17 50	At sea.
12 48	337 39	July 1846.	Bérard.	17 35	−0 42	16 53	At sea.
19 06	337 43	1832.	FitzRoy.	17 39	+0 45	18 24	At sea.
18 42	337 50	Nov. 1839.	Ross.	17 58	0 00	17 58	At sea†.
19 31	338 03	1832.	FitzRoy.	18 06	+0 45	18 51	At sea.
11 05	338 03	Sept. 1837.	Vaillant.	16 13	+0 15	16 28	At sea.
10 11	338 56	Sept. 1837.	Vaillant.	16 27	+0 15	16 42	At sea.
11 05	338 59	Sept. 1837.	Vaillant.	16 36	+0 15	16 51	At sea.
16 51	339 39	Feb. 1836.	Vaillant.	19 48	+0 26	20 14	At sea.
10 48	339 41	Sept. 1837.	Vaillant.	16 06	+0 15	16 21	At sea.
13 41	339 42	Mar. 1836.	Vaillant.	17 12	+0 25	17 37	At sea.
19 40	340 09	Feb. 1836.	Vaillant.	19 47	+0 25	20 12	At sea.
11 40	344 15	Oct. 1846.	Denham.	19 12	−0 40	18 32	Guancho.
11 33	344 21	Sept. 1846.	Denham.	19 10	−0 40	18 30	Bulama.
11 52	344 23	Sept. 1846.	Denham.	20 13	−0 40	19 33	Bissao.
			Between the latitudes of 10° and 0°.				
6 44	298 45	Jan. 1843.	Schomburgk.	− 3 59	−0 06	− 4 05	Fork of Wenama and Cuguori Rivers.
4 57	298 59	Nov. 1842.	Schomburgk.	− 4 11	−0 06	− 4 17	Near Mount Roraima.
4 17	299 42	Oct. 1842.	Schomburgk.	− 4 00	−0 05	− 4 05	Macusi Village, Pakaraima Mts.
3 22	299 48	Sept. 1842.	Schomburgk.	− 4 37	−0 05	− 4 42	Junction of Cotinger and Tacuter Rivers.
8 25	300 24	April 1841.	Schomburgk.	− 2 50	−0 03	− 2 53	River Guainia.
3 39	300 40	Mar. 1842.	Schomburgk.	− 4 00	−0 05	− 4 05	Pirara, River Rupunuri.
6 24	301 18	Dec. 1843.	Schomburgk.	− 3 06	−0 08	− 3 14	Penal Settlement.
6 49	301 49	Sept. 1841.	Schomburgk.	− 2 44	−0 03	− 2 47	Georgetown.
1 25	301 54	July 1843.	Schomburgk.	− 3 57	−0 05	− 4 02	Rio Trombetas.
2 02	303 32	Aug. 1843.	Schomburgk.	− 3 40	−0 06	− 3 46	Pianogholo Village.
9 39	326 10	May 1846.	Sulivan.	+12 47	−0 39	+12 08	At sea†.
2 04	329 37	July 1830.	Erman.	10 12	+1 11	11 23	At sea.
4 01	329 42	July 1830.	Erman.	11 08	+1 11	12 19	At sea.

TABLE XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of 10° and 0° (continued).							
5° 30′	329° 48′	May 1846.	Sulivan.	13° 57′	−0° 51′	13° 06′	At sea†.
4 45	330 08	May 1846.	Sulivan.	12 53	−0 51	12 02	At sea†.
2 05	330 11	May 1846.	Sulivan.	12 45	−0 51	11 54	At sea†.
8 22	330 16	May 1839.	Du Petit-Thouars.	13 04	+0 05	13 09	At sea.
0 55	330 36	Dec. 1832.	FitzRoy.	8 22	+0 56	9 18	At sea.
0 55	330 42	Dec. 1839.	Ross.	11 50	0 00	11 50	St. Paul's Rocks.
3 39	330 49	July 1836.	FitzRoy.	10 27	+0 28	10 55	At sea.
2 32	330 53	Dec. 1836.	FitzRoy.	10 23	+0 24	10 47	At sea.
1 20	330 55	Dec. 1832.	FitzRoy.	10 39	+0 56	11 35	At sea.
3 48	330 58	May 1846.	Sulivan.	13 04	−0 51	12 13	At sea†.
2 49	331 06	May 1846.	Sulivan.	12 58	−0 51	12 07	At sea†.
1 57	331 38	Nov. 1839.	Ross.	13 16	0 00	13 16	At sea†.
2 10	332 10	Dec. 1832.	FitzRoy.	11 08	+0 56	12 04	At sea.
3 18	332 46	Nov. 1839.	Ross.	12 18	0 00	12 18	At sea†.
5 45	332 49	1836.	FitzRoy.	11 26	+0 28	11 54	At sea.
8 50	332 58	1832.	FitzRoy.	12 44	+0 56	13 40	At sea.
5 26	332 59	May 1839.	Du Petit-Thouars.	14 30	+0 05	14 35	At sea.
8 58	333 21	July 1830.	Erman.	12 21	+1 01	13 22	At sea.
6 46	333 52	Nov. 1839.	Ross.	14 58	0 00	14 58	At sea†.
3 37	333 52	Jan. 1837.	Du Petit-Thouars.	13 19	+0 24	13 43	At sea.
5 13	334 35	Jan. 1837.	Du Petit-Thouars.	15 14	+0 24	15 38	At sea.
2 51	334 38	May 1839.	Du Petit-Thouars.	14 10	+0 05	14 15	At sea.
9 36	335 04	Sept. 1842.	Bérard.	15 00	−0 17	14 43	At sea.
7 24	335 32	Jan. 1837.	Du Petit-Thouars.	16 02	+0 19	16 21	At sea.
0 09	335 35	May 1839.	Du Petit-Thouars.	14 53	+0 05	14 58	At sea.
8 19	336 05	Sept. 1842.	Bérard.	15 30	−0 17	15 13	At sea.
7 09	336 51	Sept. 1842.	Bérard.	15 30	−0 17	15 13	At sea.
6 48	336 52	Sept. 1842.	Bérard.	14 00	−0 17	13 43	At sea.
9 24	337 22	Jan. 1847.	Stanley.	16 06	−0 45	15 21	At sea†.
6 40	337 22	Jan. 1847.	Stanley.	16 52	−0 49	16 03	At sea†.
5 50	337 25	July 1846.	Bérard.	15 11	−0 45	14 26	At sea.
5 26	337 33	Jan. 1847.	Stanley.	17 00	−0 49	16 11	At sea†.
1 11	337 35	Jan. 1847.	Stanley.	16 14	−0 49	15 25	At sea†.
4 38	338 00	Sept. 1842.	Bérard.	15 00	−0 17	14 43	At sea.
4 34	338 02	Jan. 1847.	Stanley.	17 00	−0 49	16 11	At sea†.
1 19	338 07	Oct. 1842.	Bérard.	16 30	−0 19	16 11	At sea.
2 08	338 09	Jan. 1847.	Stanley.	16 07	−0 56	15 11	At sea†.
4 19	338 14	Jan. 1847.	Stanley.	16 31	−0 56	15 35	At sea†.
4 56	338 38	Sept. 1842.	Bérard.	14 20	−0 19	14 01	At sea.
8 45	338 53	Mar. 1836.	Vaillant.	17 13	+0 23	17 36	At sea.
9 33	339 19	Sept. 1837.	Vaillant.	16 46	+0 15	17 01	At sea.
5 17	339 20	Sept. 1842.	Bérard.	15 00	+0 19	15 19	At sea.
6 21	339 21	Mar. 1836.	Vaillant.	17 13	+0 23	17 36	At sea.
8 48	339 24	Sept. 1837.	Vaillant.	16 39	+0 15	16 54	At sea.
0 46	339 26	Jan. 1846.	Bérard.	16 46	−0 49	15 57	At sea.
3 14	340 09	Sept. 1842.	Bérard.	15 30	−0 18	15 12	At sea.
2 50	340 13	Mar. 1836.	Vaillant.	17 47	+0 23	18 10	At sea.
0 43	340 14	Mar. 1836.	Vaillant.	17 12	+0 23	17 35	At sea.
2 50	340 40	Sept. 1842.	Bérard.	15 30	−0 18	15 12	At sea.
8 21	340 55	Sept. 1837.	Bérard.	17 21	+0 15	17 36	At sea.
6 18	341 50	Sept. 1837.	Bérard.	16 18	+0 15	16 33	At sea.
4 30	342 06	Sept. 1837.	Bérard.	16 42	+0 15	16 57	At sea.
0 34	343 22	Sept. 1837.	Bérard.	17 15	+0 14	17 29	At sea.
9 27	346 12	Jan. 1836.	Vidal.	17 43	+0 24	18 07	Isles de Los.
8 30	346 44	Feb. 1836.	Vidal.	18 52	+0 24	19 16	Sierra Leone.
8 30	346 44	June 1836.	Vidal.	19 06	+0 21	19 27	Sierra Leone.

TABLE XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
			Between the latitudes of 10° and 0° (continued).				
8° 30′	346° 44′	Dec. 1836.	Vidal.	20° 12′	+0° 18′	20° 30′	Sierra Leone.
8 30	346 44	Sept. 1836.	Denham.	19 36	−0 33	19 03	Sierra Leone.
7 39	346 56	Dec. 1836.	Vidal.	19 17	+0 18	19 35	Moot Island.
7 00	348 21	Dec. 1837.	Vidal.	18 53	+0 11	19 04	Gallinas.
6 19	349 11	Dec. 1837.	Vidal.	19 29	+0 11	19 40	Cape Mesurada.
6 09	349 11	Jan. 1837.	Vidal.	20 07	+0 16	20 23	Mourovia.
4 22	352 16	Feb. 1836.	Vidal.	20 00	+0 11	20 11	Cape Palmas.
4 22	352 16	Dec. 1845.	Denham.	19 05	−0 18	18 47	Cape Palmas.
4 45	357 54	May 1837.	Vidal.	20 03	0 00	20 03	Cape Three Points.
4 48	358 03	April1838.	Vidal.	20 37	0 00	20 37	Dix Cove.
5 06	358 46	April1838.	Vidal.	20 11	0 00	20 11	Cape-Coast Castle.
5 10	358 54	April1838.	Vidal.	20 13	0 00	20 13	Annamaboe.
5 32	359 49	April1838.	Vidal.	20 18	0 00	20 18	Accra.
5 32	359 49	Jan. 1846.	Denham.	20 39	0 00	20 39	Accra.
5 55	1 00	May 1846.	Denham.	19 55	0 00	19 55	Quitta.
6 13	1 36	Jan. 1846.	Denham.	20 21	0 00	20 21	Little Popoe.
6 19	2 05	Jan. 1846.	Denham.	20 08	0 00	20 08	Whydah.
6 24	2 53	Jan. 1846.	Denham.	20 30	0 00	20 30	Badagry.
4 32	5 41	May 1846.	Denham.	19 50	0 00	19 50	Middleton River.
7 07	7 49	1835.	Allen.	19 51	0 00	19 51	Sterling.
3 46	8 45	Mar. 1836.	Vidal.	19 45	0 00	19 45	Point William.
3 35	8 45	Mar. 1836.	Vidal.	19 50	0 00	19 50	Fernando Po.
3 46	8 48	Jan. 1846.	Denham.	19 04	0 00	19 04	Fernando Po.
6 27	9 13	1835.	Allen.	20 36	0 00	20 36	Rabba.
0 55	9 20	Mar. 1836.	Vidal.	20 04	0 00	20 04	Corisco Bay.
3 55	9 30	April1836.	Vidal.	19 46	0 00	19 46	Cameroons River.
			Between the latitudes of 0° and −10°.				
−1 28	311 36	Sept. 1830.	Foster.	− 1 14	+0 57	− 0 17	Para.
−2 31	315 48	Aug. 1830.	Foster.	+ 0 31	+0 57	+ 1 28	Maranham.
−0 58	319 26	Aug. 1842.	Jehenne.	5 47	−0 17	5 30	At sea.
−3 18	321 36	Aug. 1842.	Jehenne.	6 24	−0 17	6 07	At sea.
−3 41	323 46	Aug. 1842.	Jehenne.	6 47	−0 19	6 28	At sea.
−8 04	325 08	Aug. 1836.	FitzRoy.	5 54	+0 34	6 28	Pernambuco.
−8 03	325 10	Aug. 1836.	FitzRoy.	5 10	+0 34	5 44	At sea.
−7 28	326 48	Jan. 1837.	Du Petit-Thouars.	9 45	+0 28	10 13	At sea.
−3 51	327 26	Jan. 1837.	Du Petit-Thouars.	9 30	+0 27	9 57	At sea.
−7 16	327 27	Dec. 1839.	Ross.	8 57	0 00	8 57	At sea†.
−3 51	327 35	Feb. 1832.	FitzRoy.	7 53	+1 21	9 14	Fernando de Noronha.
−2 36	327 52	Jan. 1837.	Du Petit-Thouars.	10 10	+0 27	10 37	At sea.
−3 09	327 58	Feb. 1832.	FitzRoy.	7 54	+1 20	9 14	At sea.
−5 04	327 59	Feb. 1832.	FitzRoy.	7 45	+1 20	9 05	At sea.
−9 40	328 01	July 1830.	Erman.	8 39	+1 35	10 14	At sea.
−3 29	328 03	Feb. 1832.	FitzRoy.	8 00	+1 15	9 15	At sea.
−9 47	328 07	Dec. 1839.	Ross.	8 39	0 00	8 39	At sea†.
−7 57	328 31	July 1830.	Erman.	9 01	+1 38	10 39	At sea.
−3 02	328 41	Dec. 1839.	Ross.	10 15	0 00	10 15	At sea†.
−6 21	328 57	July 1830.	Erman.	8 53	+1 38	10 31	At sea.
−9 47	329 04	May 1846.	Sulivan.	9 03	−1 14	7 49	At sea†.
−8 18	329 05	May 1846.	Sulivan.	9 27	−1 14	8 13	At sea†.
−5 02	329 06	Aug. 1842.	Jehenne.	9 27	−0 27	9 00	At sea.
−6 46	329 07	May 1846.	Sulivan.	9 46	−1 05	8 41	At sea†.
−3 18	329 11	May 1846.	Sulivan.	9 50	−1 00	8 50	At sea†.
−5 10	329 16	May 1846.	Sulivan.	9 46	−1 04	8 42	At sea†.
−3 23	329 16	July 1830.	Erman.	9 17	+1 25	10 42	At sea.

TABLE XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
			Between the latitudes of 0° and −10° (continued).				
− 1° 04′	329° 20′	Jan. 1837.	Du Petit-Thouars.	12° 20′	+0° 26′	12° 46′	At sea.
− 1 21	329 29	July 1830.	Erman.	9 19	+1 21	10 40	At sea.
− 2 50	329 34	May 1846.	Sulivan.	10 18	−1 00	9 18	At sea†.
− 0 35	329 42	July 1830.	Erman.	9 51	+1 21	11 12	At sea.
− 0 28	329 42	Feb. 1832.	FitzRoy.	8 10	+1 15	9 25	At sea.
− 0 01	330 01	Feb. 1832.	FitzRoy.	8 58	+1 15	10 13	At sea.
− 0 46	330 03	May 1846.	Sulivan.	10 54	−0 55	9 59	At sea†.
− 0 07	330 08	Dec. 1839.	Ross.	10 35	0 00	10 35	At sea†.
− 9 18	330 30	Oct. 1842.	Bérard.	11 00	−0 27	10 33	At sea.
− 7 47	330 48	Jan. 1847.	Stanley.	13 41	−1 17	12 24	At sea†.
− 5 59	331 08	Aug. 1842.	Jehenne.	13 04	−0 25	12 39	At sea.
− 7 02	332 02	Oct. 1842.	Bérard.	13 00	−0 25	12 35	At sea.
− 4 58	332 10	Jan. 1847.	Stanley.	14 34	−1 11	13 23	At sea†.
− 8 02	333 44	Sept. 1836.	Vaillant.	11 30	+0 33	12 03	At sea.
− 2 34	333 50	Jan. 1847.	Stanley.	14 27	−1 05	13 22	At sea†.
− 3 10	334 09	Oct. 1842.	Bérard.	15 45	−0 24	15 21	At sea.
− 1 40	335 01	Oct. 1842.	Bérard.	15 00	−0 24	14 36	At sea.
− 5 15	335 26	1836.	Vaillant.	13 46	+0 35	14 21	At sea.
− 0 41	335 40	Oct. 1842.	Bérard.	15 00	−0 24	14 36	At sea.
− 7 48	335 46	Aug. 1842.	Jehenne.	14 29	−0 26	14 03	At sea.
− 0 19	335 50	Jan. 1847.	Stanley.	15 05	−1 10	13 55	At sea†.
− 1 52	336 43	May 1839.	Du Petit-Thouars.	14 48	+0 04	14 52	At sea.
− 3 38	337 28	Mar. 1836.	Vaillant.	14 30	+0 36	15 06	At sea.
− 3 18	338 45	May 1839.	Du Petit-Thouars.	15 58	+0 04	16 02	At sea.
− 1 15	340 01	Mar. 1836.	Vaillant.	14 37	+0 33	15 10	At sea.
− 0 40	340 10	Jan. 1846.	Bérard.	17 17	−0 52	16 25	At sea.
− 2 56	341 10	Jan. 1846.	Bérard.	17 47	−0 52	16 55	At sea.
− 4 29	341 16	May 1839.	Du Petit-Thouars.	16 33	+0 05	16 38	At sea.
− 9 30	342 28	1836.	FitzRoy.	15 56	+0 35	16 31	At sea.
− 4 45	342 39	Jan. 1846.	Bérard.	19 01	−0 54	18 07	At sea.
− 5 55	344 18	May 1839.	Du Petit-Thouars.	18 46	+0 05	18 51	At sea.
− 6 38	344 19	Jan. 1846.	Bérard.	19 27	−0 54	18 33	At sea.
− 1 51	344 47	Sept. 1837.	Vaillant.	17 47	+0 20	18 07	At sea.
− 0 44	344 58	Sept. 1837.	Vaillant.	17 34	+0 20	17 54	At sea.
− 5 12	345 04	Sept. 1837.	Vaillant.	18 52	+0 22	19 14	At sea.
− 2 56	345 13	Sept. 1837.	Vaillant.	17 53	+0 20	18 13	At sea.
− 7 55	345 35	June 1846.	Bérard.	19 16	−0 58	18 18	Anchorage, Ascension.
− 7 54	345 36	May 1839.	Du Petit-Thouars.	18 31	+0 04	18 35	Anchorage, Ascension.
− 7 54	345 36	1836.	FitzRoy.	17 36	+0 31	18 07	Anchorage, Ascension.
− 7 11	345 39	Sept. 1837.	Vaillant.	19 13	+0 20	19 33	At sea.
− 8 17	346 09	May 1839.	Du Petit-Thouars.	18 54	+0 04	18 58	At sea.
− 8 49	346 30	Sept. 1837.	Vaillant.	17 58	+0 20	18 18	At sea.
− 9 52	347 26	1836.	FitzRoy.	17 43	+0 31	18 14	At sea.
− 9 30	347 48	June 1846.	Bérard.	19 16	−0 58	18 18	At sea.
− 9 49	347 55	May 1839.	Du Petit-Thouars.	19 37	+0 04	19 41	At sea.
− 1 21	5 38	1829.	Boteler.	21 01	+0 31	21 32	Anno Bona.
			Between the latitudes of −10° and −20°.				
−18 25	321 05	Dec. 1843.	Pasley.	3 10	−0 38	2 32	At sea.
−18 14	321 08	1832.	FitzRoy.	1 04	+1 10	2 14	At sea.
−17 13	321 12	1832.	FitzRoy.	1 08	+1 10	2 18	At sea.
−16 35	321 12	1832.	FitzRoy.	1 52	+1 10	3 02	At sea.
−18 59	321 16	1832.	FitzRoy.	1 14	+1 10	2 24	At sea.
−17 58	321 18	Mar. 1832.	FitzRoy.	2 00	+1 13	3 13	Abrolhos Island.
−15 01	321 19	1832.	FitzRoy.	1 30	+1 10	2 40	At sea.
−13 25	321 23	1832.	FitzRoy.	2 08	+1 10	3 18	At sea.

TABLE XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −10° and −20° (continued).							
−18° 03′	321° 24′	1832.	FitzRoy.	2° 12′	+1° 10′	3° 22′	At sea.
−13 11	321 29	1832.	FitzRoy.	2 09	+1 10	3 19	At sea.
−12 59	321 29	Feb. 1832.	FitzRoy.	4 18	+1 14	5 32	Bahia.
−12 59	321 30	Oct. 1842.	Bérard.	3 30	−0 25	3 05	At sea.
−13 09	321 30	1836.	FitzRoy.	2 44	+0 33	3 17	At sea.
−13 33	321 35	1832.	FitzRoy.	1 34	+1 10	2 44	At sea.
−15 27	321 36	1832.	FitzRoy.	2 48	+1 10	3 58	At sea.
−16 20	321 36	1832.	FitzRoy.	1 59	+1 10	3 09	At sea.
−13 39	321 36	Oct. 1842.	Bérard.	4 00	−0 25	3 35	At sea.
−17 33	321 37	1832.	FitzRoy.	2 16	+1 10	3 26	At sea.
−14 42	321 38	1832.	FitzRoy.	2 20	+1 10	3 30	At sea.
−14 22	321 51	Oct. 1842.	Bérard.	4 30	−0 25	4 05	At sea.
−12 38	322 14	1836.	FitzRoy.	3 14	+0 32	3 46	At sea.
−16 25	322 21	Oct. 1842.	Bérard.	3 00	−0 25	2 35	At sea.
−17 54	322 29	1832.	FitzRoy.	2 20	+1 10	3 30	At sea.
−12 42	322 35	Oct. 1842.	Bérard.	7 00	−0 25	6 35	At sea.
−15 20	322 38	1832.	FitzRoy.	3 03	+1 10	4 13	At sea.
−12 42	322 45	1836.	FitzRoy.	3 31	+0 32	4 03	At sea.
−16 29	323 03	1832.	FitzRoy.	3 44	+1 10	4 54	At sea.
−17 42	323 06	Oct. 1842.	Bérard.	4 30	−0 27	4 03	At sea.
−12 48	323 13	1836.	FitzRoy.	4 18	+0 32	4 50	At sea.
−17 47	323 24	Jan. 1837.	Du Petit-Thouars.	7 20	+0 29	7 49	At sea.
−17 41	323 43	Jan. 1847.	Stanley.	7 00	−1 06	5 54	At sea†.
−19 58	323 49	Oct. 1842.	Bérard.	3 45	−0 27	3 18	At sea.
−18 10	324 04	1832.	FitzRoy.	3 01	+1 11	4 12	At sea.
−18 48	324 17	Mar. 1836.	Vaillant.	3 41	+0 35	4 16	At sea.
−11 54	324 22	Oct. 1842.	Bérard.	8 20	−0 27	7 53	At sea.
−18 57	324 24	July 1830.	Erman.	4 21	+1 35	5 56	At sea.
−15 10	324 45	Jan. 1837.	Du Petit-Thouars.	7 35	+0 28	8 03	At sea.
−19 45	324 50	July 1830.	Erman.	3 25	+1 35	5 00	At sea.
−19 35	324 59	July 1830.	Erman.	4 06	+1 35	5 41	At sea.
−11 46	325 25	Oct. 1842.	Bérard.	8 40	−0 26	8 14	At sea.
−14 52	325 26	Jan. 1847.	Stanley.	8 13	−1 06	7 07	At sea†.
−17 49	325 36	July 1830.	Erman.	4 41	+1 35	6 16	At sea.
−16 48	325 42	Mar. 1836.	Vaillant.	4 56	+0 35	5 31	At sea.
−11 55	325 50	Jan. 1837.	Du Petit-Thouars.	8 12	+0 28	8 40	At sea.
−16 45	326 02	July 1830.	Erman.	5 15	+1 35	6 54	At sea.
−14 43	326 49	July 1830.	Erman.	6 29	+1 35	8 04	At sea.
−15 12	326 52	Mar. 1836.	Vaillant.	6 45	+0 38	7 23	At sea.
−13 01	327 25	July 1830.	Erman.	7 00	+1 35	8 35	At sea.
−11 21	327 45	July 1830.	Erman.	7 18	+1 35	8 53	At sea.
−10 49	327 46	Oct. 1842.	Bérard.	10 45	−0 27	10 18	At sea.
−12 48	327 58	Jan. 1847.	Stanley.	9 01	−1 10	7 51	At sea†.
−13 15	328 35	Mar. 1836.	Vaillant.	8 06	+0 38	8 44	At sea.
−12 28	329 00	Dec. 1839.	Ross.	8 25	0 00	8 25	At sea†.
−18 11	329 06	May 1846.	Sulivan.	9 11	−1 08	8 03	At sea†.
−12 29	329 08	May 1846.	Sulivan.	9 13	−1 08	8 05	At sea†.
−15 35	329 16	May 1846.	Sulivan.	8 31	−1 08	7 23	At sea†.
−17 20	329 16	May 1846.	Sulivan.	9 01	−1 08	7 53	At sea†.
−14 17	329 19	May 1846.	Sulivan.	9 00	−1 08	7 52	At sea†.
−10 15	329 25	Jan. 1847.	Stanley.	12 28	−1 12	11 16	At sea†.
−14 55	329 53	Dec. 1839.	Ross.	8 33	0 00	8 33	At sea†.
−19 02	329 58	May 1846.	Sulivan.	8 58	−1 08	7 50	At sea†.
−11 46	330 28	Mar. 1836.	Vaillant.	8 00	+0 40	8 40	At sea.
−16 57	330 30	Dec. 1839.	Ross.	9 09	0 00	9 09	At sea†.
−19 07	330 42	Dec. 1839.	Ross.	9 48	0 00	9 48	At sea†.
−12 08	331 05	1836.	FitzRoy.	8 40	+0 36	9 16	At sea.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −10° and −20° (continued).							
−10° 05′	331° 49′	Mar. 1836.	Vaillant.	° 9 24	+ 0 46	° 10 04	At sea.
−11 25	336 37	1836.	FitzRoy.	13 06	+ 0 36	13 42	At sea.
−10 06	340 27	Aug. 1842.	Jehenne.	15 23	− 0 28	14 55	At sea.
−10 07	341 02	1836.	FitzRoy.	15 57	+ 0 38	16 35	At sea.
−11 10	342 37	Aug. 1842.	Jehenne.	16 00	− 0 28	15 32	At sea.
−11 59	344 10	June 1846.	Bérard.	21 00	− 1 10	19 50	At sea.
−12 09	345 01	Aug. 1842.	Jehenne.	17 36	− 0 28	17 08	At sea.
−19 20	345 44	Jan. 1840.	Ross.	18 44	0 00	18 44	At sea†.
−18 43	346 00	Jan. 1840.	Ross.	17 46	0 00	17 46	At sea†.
−17 37	346 23	Jan. 1840.	Ross.	19 26	0 00	19 26	At sea†.
−17 08	346 43	Jan. 1840.	Ross.	20 12	0 00	20 12	At sea†.
−13 07	347 00	Aug. 1842.	Jehenne.	19 41	− 0 26	19 15	At sea.
−16 41	347 07	Jan. 1840.	Ross.	19 32	0 00	19 32	At sea†.
−16 22	347 25	Jan. 1840.	Ross.	18 18	0 00	18 18	At sea†.
−10 34	347 55	Sept. 1837.	Vaillant.	18 05	+ 0 24	18 29	At sea.
−15 22	347 58	Jan. 1840.	Ross.	20 52	0 00	20 52	At sea†.
−15 24	348 06	Jan. 1840.	Ross.	20 40	0 00	20 40	At sea†.
−15 31	348 15	Jan. 1840.	Ross.	20 16	0 00	20 16	At sea†.
−15 44	348 15	Jan. 1840.	Ross.	19 10	0 00	19 10	At sea†.
−15 37	348 27	Jan. 1840.	Ross.	19 11	0 00	19 11	At sea†.
−15 40	348 35	Jan. 1840.	Ross.	18 56	0 00	18 56	At sea†.
−11 22	349 32	May 1839.	Du Petit-Thouars.	20 14	+ 0 06	20 20	At sea.
−12 25	349 43	Sept. 1837.	Vaillant.	18 40	+ 0 23	19 03	At sea.
−14 22	349 54	Jan. 1840.	Ross.	19 31	0 00	19 31	At sea†.
−14 11	350 28	Jan. 1840.	Ross.	21 24	0 00	21 24	At sea†.
−14 38	350 30	Jan. 1840.	Ross.	21 33	0 00	21 33	At sea†.
−13 02	350 53	1836.	FitzRoy.	19 56	+ 0 33	20 29	At sea.
−12 40	351 06	May 1839.	Du Petit-Thouars.	21 16	+ 0 06	21 22	At sea.
−14 08	351 32	Jan. 1840.	Ross.	21 32	0 00	21 32	At sea†.
−14 36	351 53	Jan. 1840.	Ross.	21 08	0 00	21 08	At sea†.
−15 04	351 57	Jan. 1840.	Ross.	21 10	0 00	21 10	At sea†.
−14 11	352 00	Jan. 1840.	Ross.	21 06	0 00	21 06	At sea†.
−13 34	352 02	Jan. 1840.	Ross.	22 09	0 00	22 09	At sea†.
−15 26	352 20	Jan. 1840.	Ross.	21 39	0 00	21 39	At sea†.
−15 27	352 30	Jan. 1840.	Ross.	21 27	0 00	21 27	At sea†.
−14 28	352 52	May 1839.	Du Petit-Thouars.	22 18	+ 0 05	22 23	At sea.
−18 29	352 55	Feb. 1840.	Ross.	23 11	0 00	23 11	At sea†.
−17 38	353 19	Feb. 1840.	Ross.	21 37	0 00	21 37	At sea†.
−15 15	353 21	Jan. 1840.	Ross.	21 29	0 00	21 29	At sea†.
−17 10	353 33	Feb. 1840.	Ross.	20 54	0 00	20 54	At sea†.
−15 21	354 07	Jan. 1840.	Ross.	23 27	0 00	23 27	At sea†.
−15 55	354 17	Feb. 1840.	Ross.	22 53	0 00	22 53	Anchorage at St. Helena.
−15 55	354 17	June 1846.	Bérard.	23 11	− 0 58	22 13	Anchorage at St. Helena.
−15 55	354 17	May 1839.	Du Petit-Thouars.	22 17	+ 0 06	22 23	Anchorage at St. Helena.
−15 57	354 19	Jan. 1841.	Magnetical Observ.	22 51	− 0 09	22 42	St. Helena.
−15 57	354 26	1836.	FitzRoy.	19 43	+ 0 33	20 16	At sea.
−16 27	355 24	Aug. 1842.	Jehenne.	24 03	− 0 25	23 38	At sea.
−19 27	355 32	June 1846.	Bérard.	23 20	− 1 01	22 19	At sea.
−16 13	355 34	June 1846.	Bérard.	23 11	− 1 01	22 10	At sea.
−18 59	356 05	June 1846.	Bérard.	23 20	− 1 01	22 19	At sea.
−17 04	356 33	Sept. 1837.	Vaillant.	22 28	+ 0 22	22 50	At sea.
−17 13	356 45	June 1846.	Bérard.	23 21	− 1 01	22 20	At sea.
−18 12	356 55	June 1846.	Bérard.	24 59	− 1 01	23 58	At sea.
−18 52	357 15	Aug. 1842.	Jehenne.	25 15	− 0 25	25 20	At sea.
−29 00	300 56	Jan. 1846.	Sulivan.	−10 40	− 0 24	−11 04	Rio Parana.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −20° and −30°.							
−27 27	301 16	Jan. 1846.	Sulivan.	− 9 24	−0 24	− 9 48	Corrientes Fort.
−27 26	311 25	June 1832.	FitzRoy.	− 6 30	+1 00	− 5 30	St. Catherine.
−29 53	311 48	June 1832.	FitzRoy.	− 6 27	+1 00	− 5 27	At sea.
−27 56	312 42	Feb. 1837.	Du Petit-Thouars.	− 4 30	+0 23	− 4 07	At sea.
−28 41	313 39	April 1836	Vaillant.	− 4 12	+0 30	− 3 42	At sea.
−27 16	313 44	June 1832.	FitzRoy.	− 5 10	+1 00	− 4 10	At sea.
−27 14	314 10	June 1832.	FitzRoy.	− 4 34	+1 00	− 3 34	At sea.
−26 09	314 18	Feb. 1837.	Du Petit-Thouars.	− 2 44	+0 23	− 2 21	At sea.
−28 15	314 53	May 1830.	Erman.	− 4 10	+1 16	− 2 54	At sea.
−26 18	315 28	May 1830.	Erman.	− 3 31	+1 16	− 2 15	At sea.
−26 49	315 55	April 1836.	Vaillant.	− 3 06	+0 30	− 2 36	At sea.
−26 33	316 12	June 1832.	FitzRoy.	− 3 39	+1 03	− 2 36	At sea.
−24 12	316 23	Feb. 1837.	Du Petit-Thouars.	− 2 04	+0 23	− 1 41	At sea.
−24 12	316 36	May 1830.	Erman.	− 2 10	+1 20	− 0 50	At sea.
−23 30	316 40	Feb. 1837.	Du Petit-Thouars.	− 2 00	+0 23	− 1 37	At sea.
−24 43	316 47	May 1830.	Erman.	− 2 41	+1 20	− 1 21	At sea.
−23 46	316 49	May 1832.	Erman.	− 1 30	+1 20	− 0 10	At sea.
−23 03	316 54	June 1832.	FitzRoy.	− 1 39	+1 03	− 0 36	At sea.
−22 55	316 55	June 1832.	FitzRoy.	− 2 00	+1 03	− 0 57	Rio de Janeiro.
−22 54	316 55	June 1830.	Erman.	− 2 08	+1 20	− 0 48	Rio de Janeiro.
−22 54	316 55	April 1836.	Vaillant.	− 0 50	+0 31	− 0 19	Rio de Janeiro.
−22 54	316 55	Feb. 1837.	Du Petit-Thouars.	− 0 51	+0 23	− 0 28	Rio de Janeiro.
−22 54	316 55	July 1845.	Von Helmriecher.	− 0 13	−0 47	− 1 00	Rio de Janeiro.
−24 06	317 07	June 1832.	FitzRoy.	− 1 57	+1 03	− 0 54	At sea.
−24 00	317 09	Feb. 1847.	Stanley.	− 0 47	−1 00	− 1 47	At sea†.
−23 09	317 17	June 1830.	Erman.	− 1 39	+1 20	− 0 19	At sea.
−24 38	317 19	Jan. 1844.	Pasley.	− 1 00	−0 34	− 1 34	At sea.
−25 23	317 37	April 1836.	Vaillant.	− 1 09	+0 32	− 0 37	At sea.
−23 00	318 03	July 1828.	Foster.	− 1 07	+1 40	+ 0 33	Cape Frio.
−24 07	318 07	April 1836.	Vaillant.	− 0 30	+0 32	+ 0 02	At sea.
−23 05	318 10	April 1836.	Vaillant.	− 2 30	+0 32	− 1 58	At sea.
−29 17	318 13	Dec. 1843.	Pasley.	0 00	−0 34	− 0 34	At sea.
−23 30	318 13	June 1830.	Erman.	− 1 03	+1 20	+ 0 17	At sea.
−27 11	318 38	Jan. 1844.	Pasley.	0 00	−0 34	− 0 34	At sea.
−24 56	318 38	April 1836.	Vaillant.	− 0 23	+0 34	+ 0 11	At sea.
−22 58	318 45	June 1832.	FitzRoy.	− 0 24	+1 07	0 43	At sea.
−22 53	319 18	Feb. 1837.	Du Petit-Thouars.	+ 2 12	+0 26	2 38	At sea.
−25 59	319 19	Feb. 1847.	Stanley.	1 33	−1 04	0 29	At sea†.
−22 42	319 39	June 1832.	FitzRoy.	0 03	+1 10	1 13	At sea.
−24 48	320 23	June 1830.	Erman.	1 03	+1 30	2 33	At sea.
−20 50	320 32	Dec. 1843.	Pasley.	3 00	−0 38	2 22	At sea.
−22 07	320 39	Jan. 1847.	Stanley.	3 01	−1 06	1 55	At sea†.
−20 12	322 06	Jan. 1847.	Stanley.	5 05	−1 06	3 59	At sea†.
−27 52	322 42	Jan. 1847.	Stanley.	2 20	−1 06	1 14	At sea†.
−24 52	323 43	June 1830.	Erman.	2 20	+1 30	3 50	At sea.
−20 38	324 44	June 1830.	Erman.	3 32	+1 30	5 02	At sea.
−22 28	324 46	June 1830.	Erman.	3 33	+1 30	5 03	At sea.
−22 39	324 59	Oct. 1842.	Bérard.	3 30	−0 26	3 04	At sea.
−24 03	325 08	June 1830.	Erman.	3 12	+1 35	4 47	At sea.
−25 00	325 16	June 1830.	Erman.	2 45	+1 35	4 20	At sea.
−25 09	327 42	Oct. 1842.	Bérard.	5 00	−0 26	4 34	At sea.
−26 58	329 17	Oct. 1842.	Bérard.	4 15	−0 27	3 48	At sea.
−20 30	330 37	Dec. 1839.	Ross.	8 01	0 00	8 01	At sea†.
−21 30	330 46	Dec. 1839.	Ross.	9 43	0 00	9 43	At sea†.
−22 40	330 52	Dec. 1839.	Ross.	9 01	0 00	9 01	At sea†.
−23 19	330 56	Dec. 1839.	Ross.	7 45	0 00	7 45	At sea†.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −20° and −30° (continued).							
−27° 42′	331° 10′	Nov. 1842.	Bérard.	6° 15′	−0° 27′	5° 48′	At sea.
−24 42	332 05	Dec. 1839.	Ross.	7 08	0 00	7 08	At sea†.
−26 58	333 24	Dec. 1839.	Ross.	9 24	0 00	9 24	At sea†.
−26 37	333 26	Dec. 1839.	Ross.	8 02	0 00	8 02	At sea†.
−27 04	334 14	Dec. 1839.	Ross.	10 04	0 00	10 04	At sea†.
−27 40	335 06	Dec. 1839.	Ross.	9 37	0 00	9 37	At sea†.
−25 30	335 20	Dec. 1839.	Ross.	10 35	0 00	10 35	At sea†.
−26 55	335 21	Dec. 1839.	Ross.	9 48	0 00	9 48	At sea†.
−25 45	335 43	Dec. 1839.	Ross.	10 22	0 00	10 22	At sea†.
−26 51	337 11	Dec. 1839.	Ross.	11 10	0 00	11 10	At sea†.
−27 44	338 36	Dec. 1839.	Ross.	12 00	0 00	12 00	At sea†.
−28 15	340 08	Jan. 1840.	Ross.	13 23	0 00	13 23	At sea†.
−27 55	341 50	Jan. 1840.	Ross.	13 13	0 00	13 13	At sea†.
−27 33	342 27	Jan. 1840.	Ross.	13 41	0 00	13 41	At sea†.
−25 48	342 55	Jan. 1840.	Ross.	14 11	0 00	14 11	At sea†.
−24 39	343 02	Jan. 1840.	Ross.	14 26	0 00	14 26	At sea†.
−22 54	343 36	Jan. 1840.	Ross.	14 59	0 00	14 59	At sea†.
−20 20	345 07	Jan. 1840.	Ross.	17 50	0 00	17 50	At sea†.
−29 56	345 54	June 1846.	Bérard.	17 48	−1 14	16 34	At sea.
−27 00	346 33	Jan. 1840.	Ross.	17 53	0 00	17 53	At sea†.
−27 53	346 43	Jan. 1840.	Ross.	18 30	0 00	18 30	At sea†.
−26 10	347 18	Jan. 1840.	Ross.	17 51	0 00	17 51	At sea†.
−25 23	347 49	Jan. 1840.	Ross.	19 55	0 00	19 55	At sea†.
−28 48	348 14	Jan. 1840.	Ross.	18 19	0 00	18 19	At sea†.
−24 41	348 39	Jan. 1840.	Ross.	20 21	0 00	20 21	At sea†.
−28 05	349 16	June 1846.	Bérard.	19 56	−1 14	18 42	At sea.
−29 58	350 52	Jan. 1840.	Ross.	19 55	0 00	19 55	At sea†.
−23 32	351 04	Feb. 1840.	Ross.	21 39	0 00	21 39	At sea†.
−22 00	351 19	Feb. 1840.	Ross.	22 17	0 00	22 17	At sea†.
−20 15	352 04	Feb. 1840.	Ross.	23 12	0 00	23 12	At sea†.
−20 51	2 38	May 1839.	Du Petit-Thouars.	25 27	+0 05	25 32	At sea.
−22 17	4 36	June 1836.	FitzRoy.	24 12	+0 24	24 36	At sea.
−22 56	5 06	June 1836.	FitzRoy.	24 09	+0 24	24 33	At sea.
−25 54	7 28	April 1839.	Du Petit-Thouars.	26 28	+0 05	26 33	At sea.
−26 35	7 33	April 1839.	Du Petit-Thouars.	26 28	+0 05	26 33	At sea.
−27 35	8 05	Aug. 1842.	Jehenne.	28 00	−0 18	27 42	At sea.
−27 23	8 32	April 1839.	Du Petit-Thouars.	27 08	+0 05	27 13	At sea.
−27 48	9 50	Aug. 1837.	Vaillant.	26 06	+0 18	26 24	At sea.
−24 31	10 35	Aug. 1837.	Vaillant.	25 11	+0 18	25 29	At sea.
−29 33	10 58	April 1839.	Du Petit-Thouars.	26 51	+0 05	26 56	At sea.
−29 05	12 01	Aug. 1837.	Vaillant.	26 02	+0 18	26 20	At sea.
Between the latitudes of −30° and −40°.							
−38 44	297 45	1833.	FitzRoy.	−15 20	+0 16	−15 04	Argentino Fort.
−39 58	297 53	1833.	FitzRoy.	−15 50	+0 16	−15 34	Indian Head.
−39 52	297 54	1833.	FitzRoy.	−15 40	+0 16	−15 24	Colorado River.
−39 27	297 57	1833.	FitzRoy.	−15 30	+0 16	−15 14	Labyrinth Head.
−39 16	298 00	1833.	FitzRoy.	−15 20	+0 16	−15 04	Ariadne Island.
−38 57	298 01	1833.	FitzRoy.	−15 00	+0 19	−14 41	Point Johnson.
−39 11	298 06	1833.	FitzRoy.	−15 10	+0 19	−14 51	Zuraita Island.
−38 59	298 20	1833.	FitzRoy.	−14 50	+0 19	−14 31	Mount Hermoso.
−38 57	298 42	Aug. 1833.	FitzRoy.	−15 10	+0 20	−14 50	At sea.
−39 10	299 19	Aug. 1833.	FitzRoy.	−15 07	+0 26	−14 41	At sea.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −30° and −40° (continued).							
−31 41	299 34	Jan. 1846.	Sulivan.	−13 14	−0 24	−13 38	Bahada de Santa Fe.
−38 39	301 12	1833.	FitzRoy.	−14 00	+0 26	−13 34	Black Point.
−34 36	301 38	1833.	FitzRoy.	−11 40	+0 26	−11 14	Buenos Ayres.
−33 41	301 53	Sept. 1845.	Sulivan.	−12 06	−0 23	−12 29	River Uruquay.
−32 20	301 55	Sept. 1845.	Sulivan.	−11 14	−0 23	−11 37	Sandy Island.
−34 28	302 11	Aug. 1844.	Sulivan.	−11 36	−0 18	−11 54	Colonia.
−38 17	302 21	1833.	FitzRoy.	−14 00	+0 28	−13 32	Point San Andres.
−34 42	302 28	Nov. 1832.	FitzRoy.	−11 33	+0 32	−11 01	At sea.
−38 06	302 31	1833.	FitzRoy.	−13 50	+0 29	−13 21	Cape Corientes.
−35 43	302 41	1833.	FitzRoy.	−12 30	+0 29	−12 01	Rio Salado.
−35 42	302 42	1833.	FitzRoy.	−12 30	+0 29	−12 01	River Sanborombon.
−35 27	302 55	1833.	FitzRoy.	−12 30	+0 29	−12 01	Point Piedras.
−34 41	303 12	Aug. 1832.	FitzRoy.	−11 49	+0 34	−11 15	At sea.
−36 19	303 14	1833.	FitzRoy.	−13 00	+0 29	−12 31	Cape San Antonio.
−39 59	303 19	1833.	FitzRoy.	−13 30	+0 29	−13 01	Medanos Point.
−36 56	303 25	Aug. 1832.	FitzRoy.	−12 36	+0 34	−12 02	At sea.
−34 52	303 36	Aug. 1833.	FitzRoy.	−11 46	+0 29	−12 15	At sea.
−34 57	303 42	Nov. 1832.	FitzRoy.	−12 28	+0 34	−11 54	At sea.
−34 53	303 47	1833.	FitzRoy.	−12 40	+0 29	−12 11	Monte Video.
−34 53	303 47	April 1836.	Vaillant.	−10 35	+0 17	−10 18	Monte Video.
−34 54	303 48	July 1843.	Sulivan.	−10 42	−0 16	−10 58	Monte Video.
−34 54	303 48	Aug. 1844.	Sulivan.	−10 53	−0 20	−11 13	Monte Video.
−34 57	305 02	1833.	FitzRoy.	−12 28	+0 32	−11 56	Gorriti.
−35 14	305 14	April 1836.	Vaillant.	−10 57	+0 20	−10 37	At sea.
−38 37	305 46	Feb. 1837.	Du Petit-Thouars.	−10 34	+0 16	−10 18	At sea.
−35 52	306 16	April 1836.	Vaillant.	− 8 40	+0 20	− 8 20	At sea.
−34 05	306 49	April 1836.	Vaillant.	− 8 25	+0 20	− 8 05	At sea.
−35 01	306 52	April 1836.	Vaillant.	−10 14	+0 20	− 9 54	At sea.
−34 57	307 31	April 1836.	Vaillant.	− 9 10	+0 20	− 8 50	At sea.
−34 09	307 57	July 1832.	FitzRoy.	−10 27	+0 45	− 9 42	At sea.
−34 16	308 20	Feb. 1837.	Du Petit-Thouars.	− 7 28	+0 17	− 7 11	At sea.
−39 49	308 53	April 1830.	Erman.	−11 44	+0 57	−10 47	At sea.
−33 16	309 27	April 1836.	Vaillant.	− 8 18	+0 22	− 7 56	At sea.
−38 29	309 31	April 1830.	Erman.	−11 16	+0 57	−10 19	At sea.
−33 42	309 40	April 1836.	Vaillant.	− 6 56	+0 22	− 6 34	At sea.
−32 37	309 43	Aug. 1837.	Du Petit-Thouars.	− 5 37	+0 17	− 5 20	At sea.
−38 13	309 45	April 1830.	Erman.	−10 10	+1 06	− 9 04	At sea.
−37 15	310 00	April 1830.	Erman.	− 9 25	+1 06	− 8 19	At sea.
−35 47	310 33	April 1830.	Erman.	− 8 19	+1 06	− 7 13	At sea.
−34 49	310 55	April 1830.	Erman.	− 8 08	+1 06	− 7 02	At sea.
−31 09	311 03	July 1832.	FitzRoy.	− 7 50	+0 53	− 6 57	At sea.
−30 56	311 44	April 1836.	Vaillant.	− 4 44	+0 26	− 4 18	At sea.
−32 38	312 27	1830.	Erman.	− 7 17	+1 10	− 6 07	At sea.
−30 51	313 22	May 1830.	Erman.	− 5 13	+1 10	− 4 03	At sea.
−30 23	316 15	April 1846.	Sulivan.	− 4 15	−1 00	− 5 15	At sea†.
−30 12	318 18	Dec. 1843.	Pasley.	0 00	−0 35	− 0 35	At sea.
−31 55	318 30	Jan. 1844.	Pasley.	0 00	−0 35	− 0 35	At sea.
−30 06	318 45	April 1846.	Sulivan.	− 2 10	−1 00	− 3 10	At sea†.
−31 26	320 34	Jan. 1844.	Pasley.	+ 1 20	−0 36	+ 0 44	At sea.
−30 22	321 00	Jan. 1844.	Pasley.	+ 1 00	−0 36	0 24	At sea.
−31 20	322 06	Jan. 1844.	Pasley.	+ 1 17	−0 36	0 43	At sea.
−33 13	323 09	Feb. 1847.	Stanley.	+ 2 48	−1 12	1 36	At sea†.
−30 50	323 14	Feb. 1847.	Stanley.	+ 2 24	−1 12	1 12	At sea†.
−35 07	324 14	Feb. 1847.	Stanley.	+ 2 49	−1 19	1 30	At sea†.
−36 37	326 57	Feb. 1847.	Stanley.	+ 2 37	−1 24	1 13	At sea†.
−37 24	328 42	Feb. 1847.	Stanley.	+ 4 09	−1 25	2 44	At sea†.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −30° and −40° (continued).							
−36° 50′	332° 01′	Feb. 1847.	Stanley.	6° 39′	−1° 26′	5° 06′	At sea†.
−36 32	333 25	Feb. 1847.	Stanley.	7 51	−1 26	6 25	At sea†.
−31 01	335 28	Nov. 1842.	Bérard.	11 30	−0 32	10 58	At sea.
−36 42	336 14	May 1846.	Bérard.	7 54	−1 14	6 40	At sea.
−36 31	336 28	Feb. 1847.	Stanley.	10 00	−1 26	8 34	At sea†.
−31 49	337 53	Nov. 1842.	Bérard.	13 45	−0 34	12 41	At sea.
−38 26	336 42	May 1846.	Bérard.	7 45	−1 18	6 27	At sea.
−35 18	337 23	May 1846.	Bérard.	11 03	−1 14	9 49	At sea.
−33 26	339 58	May 1846.	Bérard.	12 44	−1 14	11 30	At sea.
−35 31	340 26	Feb. 1847.	Stanley.	13 07	−1 26	11 41	At sea†.
−37 01	341 09	Feb. 1847.	Stanley.	11 13	−1 26	9 47	At sea†.
−36 52	341 31	Feb. 1847.	Stanley.	11 58	−1 26	10 32	At sea†.
−32 14	342 11	June 1846.	Bérard.	13 36	−1 14	12 22	At sea.
−38 02	343 00	Feb. 1847.	Stanley.	13 07	−1 22	12 45	At sea†.
−30 41	344 38	June 1846.	Bérard.	17 16	−1 11	16 05	At sea.
−37 57	349 19	Feb. 1847.	Stanley.	14 30	−1 20	13 10	At sea†.
−34 31	350 21	Nov. 1842.	Bérard.	16 00	−0 32	15 28	At sea.
−37 27	352 40	Feb. 1847.	Stanley.	18 40	−1 20	17 20	At sea†.
−30 58	353 26	Feb. 1840.	Ross.	21 48	−0 02	21 46	At sea†.
−36 05	355 10	Feb. 1847.	Stanley.	20 02	−1 16	18 46	At sea†.
−31 32	355 37	Feb. 1840.	Ross.	21 54	−0 02	21 52	At sea†.
−34 45	355 39	Feb. 1847.	Stanley.	21 43	−1 16	20 27	At sea†.
−35 23	356 39	Feb. 1847.	Stanley.	23 08	−1 16	21 52	At sea†.
−35 30	357 00	Feb. 1847.	Stanley.	22 41	−1 16	21 25	At sea†.
−35 42	357 09	Nov. 1842.	Bérard.	21 00	−0 29	20 31	At sea.
−36 58	358 28	Feb. 1847.	Stanley.	22 16	−1 12	21 04	At sea†.
−31 01	359 26	Feb. 1840.	Ross.	23 29	0 00	23 29	At sea†.
−31 13	359 31	Feb. 1840.	Ross.	23 02	0 00	23 02	At sea†.
−30 30	359 36	Feb. 1840.	Ross.	23 08	0 00	23 08	At sea†.
−38 23	359 37	Feb. 1847.	Stanley.	22 28	−1 04	21 24	At sea†.
−31 28	359 38	Feb. 1840.	Ross.	23 41	0 00	23 41	At sea†.
−31 19	359 46	Feb. 1840.	Ross.	23 08	0 00	23 08	At sea†.
−30 37	359 48	Feb. 1840.	Ross.	23 33	0 00	23 33	At sea†.
−38 52	1 01	Feb. 1847.	Stanley.	23 41	−1 04	22 37	At sea†.
−32 00	1 48	Feb. 1840.	Ross.	24 07	−0 02	24 05	At sea†.
−32 41	4 24	Feb. 1840.	Ross.	24 49	−0 02	24 47	At sea†.
−38 19	4 37	Mar. 1847.	Stanley.	24 30	−1 04	23 26	At sea†.
−33 14	6 03	Mar. 1840	Ross.	26 48	−0 02	26 46	At sea†.
−33 29	7 48	Mar. 1840.	Ross.	27 13	−0 02	27 11	At sea†.
−33 27	9 06	Mar. 1840.	Ross.	28 27	−0 02	28 25	At sea†.
−37 10	9 28	Mar. 1847.	Stanley.	27 12	−0 59	26 13	At sea†.
−33 01	9 52	Mar. 1840.	Ross.	28 21	−0 02	28 19	At sea†.
−38 11	10 08	Nov. 1842.	Bérard.	26 00	−0 21	25 39	At sea.
−33 14	10 37	Mar. 1840.	Ross.	29 22	−0 02	29 20	At sea†.
−30 02	11 38	April 1839.	Du Petit-Thouars.	26 21	+0 06	26 27	At sea.
−36 40	12 05	Mar. 1847.	Stanley.	27 50	−0 52	26 58	At sea†.
−31 25	13 22	April 1839.	Du Petit-Thouars.	27 19	+0 05	27 24	At sea.
−35 10	13 25	Jan. 1845.	Moore and Clerk.	25 10	−0 35	25 05	At sea†.
−33 00	13 36	Mar. 1840.	Ross.	28 44	−0 02	28 42	At sea†.
−36 20	13 48	Mar. 1847.	Stanley.	28 27	−0 48	27 39	At sea†.
−35 17	14 00	Jan. 1845.	Moore and Clerk.	27 15	−0 20	26 45	At sea†.
−30 40	14 09	Aug. 1837.	Vaillant.	28 35	+0 17	28 52	At sea.
−32 53	14 21	Mar. 1840.	Ross.	29 36	−0 02	29 34	At sea†.
−38 43	14 25	Jan. 1845.	Moore and Clerk.	25 09	−0 30	24 39	At sea†.
−39 18	14 28	Jan. 1845.	Moore and Clerk.	28 20	−0 30	27 50	At sea†.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
			Between the latitudes of −30° and −40° (continued).				
−35 26	15 08	Jan. 1845.	Moore and Clerk.	28 39	−0 36	28 09	At sea†.
−32 57	15 27	Aug. 1842.	Jehenne.	31 16	−0 16	31 00	At sea.
−32 23	15 52	Mar. 1840.	Ross.	29 23	−0 02	29 21	At sea†.
−33 45	15 52	Aug. 1837.	Vaillant.	28 43	+0 18	29 01	At sea.
−32 03	15 53	Aug. 1837.	Vaillant.	27 16	+0 18	27 34	At sea.
−33 28	15 58	April1843.	Du Petit-Thouars.	26 37	+0 04	26 41	At sea.
−39 11	15 59	Mar. 1843.	Ross.	28 22	−0 21	28 01	At sea†.
−39 52	16 04	Mar. 1843.	Crozier.	26 38	−0 21	26 17	At sea†.
−35 59	16 22	Mar. 1843.	Crozier.	27 50	−0 21	27 29	At sea†.
−38 26	16 39	April1843.	Ross.	29 24	−0 21	29 03	At sea†.
−35 42	16 44	April1843.	Crozier.	27 11	−0 21	26 50	At sea†.
−32 49	16 53	Mar. 1840.	Ross.	29 29	−0 02	29 27	At sea†.
−32 33	16 55	Mar. 1840.	Ross.	29 25	−0 02	29 23	At sea†.
−33 21	17 07	Mar. 1840.	Ross.	29 34	−0 02	29 32	At sea†.
−32 59	17 08	Mar. 1840.	Ross.	29 46	−0 02	29 44	At sea†.
−34 42	17 36	Jan. 1845.	Moore and Clerk.	29 51	−0 32	29 19	At sea†.
−34 37	17 51	Mar. 1840.	Ross.	30 10	−0 02	30 08	At sea†.
−34 38	17 59	April1839.	Du Petit-Thouars.	27 45	+0 04	27 49	At sea.
−34 18	18 03	Mar. 1840.	Ross.	29 33	−0 02	29 31	At sea†.
−34 12	18 26	1840.	Ross.	29 04	−0 02	29 02	At sea†.
−34 11	18 27	April1839.	Du Petit-Thouars.	29 09	+0 04	29 13	False Bay.
−33 56	18 29	1841.	Magnetic Observ^{y}.	29 07	0 00	29 07	Cape of Good Hope.
−34 18	18 41	Mar. 1830.	Du Petit-Thouars.	29 38	+0 04	29 42	At sea.
			Between the latitudes of −40° and −50°.				
−49 39	292 05	April1834.	FitzRoy.	−20 18	+0 14	−20 04	At sea.
−49 14	292 15	1833.	RitzRoy.	−21 10	+0 16	−20 54	Wood Mount.
−49 15	292 18	1833.	FitzRoy.	−21 00	+0 16	−20 44	Sholl Point.
−49 11	292 23	1833.	FitzRoy.	−21 00	+0 16	−20 44	Port San Julian.
−49 14	292 24	1833.	FitzRoy.	−21 00	+0 16	−20 44	Desengaño.
−45 57	292 26	1833.	FitzRoy.	−19 42	+0 16	−19 26	Point Marques.
−48 10	292 30	Jan. 1834.	FitzRoy.	−20 50	+0 15	−20 35	At sea.
−46 31	292 37	1833.	FitzRoy.	−19 40	+0 16	−19 24	Murphy Head.
−45 46	292 38	1833.	FitzRoy.	−19 40	+0 16	−19 24	Cordova Head.
−48 47	292 45	Jan. 1834.	FitzRoy.	−21 28	+0 15	−21 13	At sea.
−49 10	292 45	Jan. 1834.	FitzRoy.	−19 47	+0 15	−19 32	At sea.
−46 41	292 50	1833.	FitzRoy.	−20 00	+0 16	−19 44	Bauza Head.
−48 35	293 07	1833.	FitzRoy.	−21 00	+0 16	−20 44	Lookout Point.
−45 10	293 28	1833.	FitzRoy.	−19 30	+0 16	−19 14	Malaspina Cove.
−47 49	293 37	1833.	FitzRoy.	−20 20	+0 16	−20 04	Head of Port Desire.
−48 21	293 39	1833.	FitzRoy.	−20 00	+0 16	−19 44	Watchman Cape.
−48 29	293 48	1833.	FitzRoy.	−21 00	+0 16	−20 44	Bellaco Rock.
−48 23	293 50	Jan. 1834.	FitzRoy.	−19 43	+0 15	−19 28	At sea.
−47 45	294 00	Jan. 1834.	FitzRoy.	−20 30	+0 15	−20 15	At sea.
−48 45	294 00	Jan. 1834.	FitzRoy.	−18 22	+0 15	−18 07	At sea.
−47 45	294 08	Jan. 1834.	FitzRoy.	−19 57	+0 15	−19 42	Port Desire.
−47 06	294 09	1833.	FitzRoy.	−19 20	+0 17	−19 03	Cape Three Points.
−45 04	294 12	1833.	FitzRoy.	−19 20	+0 17	−19 03	Melo Port.
−47 57	294 14	1833.	FitzRoy.	−20 50	+0 17	−20 33	Sea-Bear Bay.
−47 12	294 17	1833.	FitzRoy.	−19 30	+0 17	−19 13	Cape Blanco.
−45 04	294 19	1833.	FitzRoy.	−19 00	+0 17	−18 43	South Cape.
−44 56	294 28	1833.	FitzRoy.	−19 00	+0 17	−18 43	Blanco Islet.
−44 31	294 38	1833.	FitzRoy.	−19 08	+0 17	−18 51	Santa Elena.
−43 47	294 43	1833.	FitzRoy.	−18 30	+0 17	−18 13	Lobos Head.
−49 47	294 44	April1834.	FitzRoy.	−22 50	+0 15	−22 35	At sea.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −40° and −50° (continued).							
−44 12	294 45	1833.	FitzRoy.	−18 50	+0 17	−18 33	Atlas Point.
−47 11	294 56	Dec. 1833.	FitzRoy.	−19 50	+0 16	−19 34	Chupat River.
−43 21	294 57	April 1824.	FitzRoy.	−18 06	+0 15	−17 51	At sea.
−42 47	295 00	1833.	FitzRoy.	−17 50	+0 16	−17 34	Western Port.
−41 40	295 06	1833.	FitzRoy.	−17 50	+0 16	−17 34	Pozos Point.
−40 49	295 06	1833.	FitzRoy.	−17 40	+0 16	−17 24	Port San Antonio.
−42 08	295 33	April 1833.	FitzRoy.	−16 53	+0 16	−16 37	At sea.
−48 46	295 36	Jan. 1834.	FitzRoy.	−19 18	+0 15	−19 03	At sea.
−42 14	295 38	1833.	FitzRoy.	−17 45	+0 17	−17 28	Entrance Point.
−42 58	295 41	1833.	FitzRoy.	−17 50	+0 17	−17 33	Point Ninfas.
−42 35	295 42	1833.	FitzRoy.	−17 50	+0 17	−17 33	Pyramid.
−42 53	295 53	1833.	FitzRoy.	−17 50	+0 17	−17 33	Nuevo Head.
−41 09	296 05	1833.	FitzRoy.	−17 40	+0 17	−17 23	Belen Bluff.
−42 03	296 12	1833.	FitzRoy.	−17 50	+0 17	−17 33	Norte Point.
−42 46	296 24	1833.	FitzRoy.	−17 50	+0 17	−17 33	Delgado Point.
−42 30	296 25	1833.	FitzRoy.	−17 50	+0 17	−17 33	Valdes Port.
−40 48	297 02	1833.	FitzRoy.	−17 00	+0 17	−16 43	Del Carmen Fort.
−41 02	297 15	1833.	FitzRoy.	−17 40	+0 17	−17 23	Negro River.
−45 12	297 37	Dec. 1832.	FitzRoy.	−17 25	+0 24	−17 01	At sea.
−40 52	297 42	1833.	FitzRoy.	−17 00	+0 20	−16 40	Raza Point.
−49 29	297 45	May 1836.	Vaillant.	−19 36	+0 09	−19 27	At sea.
−49 39	297 48	Mar. 1837.	Du Petit-Thouars.	−17 00	+0 07	−16 53	At sea.
−40 36	297 51	1833.	FitzRoy.	−16 30	+0 18	−16 12	Rubia Point.
−40 46	297 54	Dec. 1832.	FitzRoy.	−15 26	+0 20	−15 06	At sea.
−40 27	298 00	Aug. 1833.	FitzRoy.	−16 16	+0 18	−15 58	At sea.
−40 27	298 06	1833.	FitzRoy.	−16 30	+0 18	−16 12	Snake Bank.
−45 26	298 18	May 1836.	Vaillant.	−16 52	+0 12	−16 40	At sea.
−40 52	298 23	Aug. 1833.	FitzRoy.	−16 42	+0 18	−16 24	At sea.
−47 30	298 27	May 1836.	Vaillant.	−16 16	+0 12	−16 04	At sea.
−42 16	298 28	Dec. 1832.	FitzRoy.	−16 12	+0 22	−15 50	At sea.
−43 56	298 35	Dec. 1832.	FitzRoy.	−16 40	+0 22	−16 18	At sea.
−44 30	298 42	Dec. 1833.	FitzRoy.	−18 14	+0 20	−17 54	At sea.
−43 14	298 43	Dec. 1832.	FitzRoy.	−16 20	+0 22	−15 58	At sea.
−41 17	298 47	Aug. 1833.	FitzRoy.	−14 23	+0 21	−14 02	At sea.
−45 30	298 58	Mar. 1837.	Du Petit-Thouars.	−15 42	+0 11	−15 31	At sea.
−43 27	300 01	Dec. 1833.	FitzRoy.	−15 46	+0 26	−15 20	At sea.
−42 44	300 29	May 1836.	Vaillant.	−14 10	+0 15	−13 55	At sea.
−42 34	301 06	Dec. 1833.	FitzRoy.	−16 01	+0 30	−15 31	At sea.
−43 05	302 50	Mar. 1837.	Du Petit-Thouars.	−14 10	+0 14	−13 56	At sea.
−40 30	303 07	May 1836.	Vaillant.	−10 57	+0 18	−10 39	At sea.
−41 56	304 55	Mar. 1837.	Du Petit-Thouars.	−14 20	+0 14	−14 06	At sea.
−40 24	306 42	Feb. 1837.	Du Petit-Thouars.	−12 05	+0 14	−11 51	At sea.
−41 41	306 48	Feb. 1837.	Du Petit-Thouars.	−13 12	+0 14	−12 58	At sea.
−44 04	307 25	April 1830.	Erman.	−13 40	+0 49	−12 51	At sea.
−48 49	10 16	Mar. 1843.	Ross.	+24 32	−0 30	+24 02	At sea.
−48 13	10 29	Mar. 1843.	Crozier.	23 56	−0 30	23 26	At sea†.
−48 27	10 51	Jan. 1845.	Moore and Clerk.	24 50	−0 47	24 03	At sea†.
−44 45	13 19	Jan. 1845.	Moore and Clerk.	26 34	−0 47	25 47	At sea†.
−46 24	13 34	Jan. 1845.	Moore and Clerk.	25 54	−0 47	25 07	At sea†.
−43 36	13 47	Mar. 1843.	Crozier.	26 40	−0 30	26 10	At sea†.
−43 28	14 32	Mar. 1843.	Ross.	28 18	−0 30	27 48	At sea†.
−40 15	14 35	Jan. 1845.	Moore and Clerk.	27 40	−0 45	26 55	At sea†.
−41 51	15 03	Mar. 1843.	Crozier.	27 05	−0 30	26 35	At sea†.
−41 38	15 12	Mar. 1843.	Ross.	28 40	−0 30	28 10	At sea†.

TABLE XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −50° and −60°.							
−53° 33′	287° 34′	1834.	FitzRoy.	−23° 35′	+0° 03′	−23° 32′	Crosstide Cape.
−53 31	287 35	1834.	FitzRoy.	−24 00	+0 03	−23 57	St. Jerome Point.
−54 35	287 38	1834.	FitzRoy.	−25 00	+0 03	−24 57	West Furies.
−53 33	287 41	1834.	FitzRoy.	−24 06	+0 03	−24 03	Bachelor River.
−54 24	287 42	1834.	FitzRoy.	−24 30	+0 03	−24 27	North Cove.
−54 02	287 45	1834.	FitzRoy.	−24 00	+0 03	−23 57	Bowles Island.
−53 11	287 47	1834.	FitzRoy.	−23 45	+0 03	−23 42	Gidley Islet.
−54 38	287 48	1834.	FitzRoy.	−25 00	+0 03	−24 57	East Furies.
−54 34	287 48	1834.	FitzRoy.	−25 00	+0 03	−24 57	Tussuck Rock.
−54 25	287 49	1834.	FitzRoy.	−24 30	+0 03	−24 27	Mount Skyring.
−54 39	287 53	1834.	FitzRoy.	−24 40	+0 03	−24 37	Cape Schomburgk.
−54 36	287 55	1834.	FitzRoy.	−24 40	+0 03	−24 37	Astrea Island.
−53 42	287 59	1834.	FitzRoy.	−24 04	+0 03	−24 01	Gallant Port.
−54 42	288 05	1834.	FitzRoy.	−24 34	+0 04	−24 30	Townshend Harbour.
−53 05	288 07	1834.	FitzRoy.	−23 56	+0 04	−23 52	Inglefield Island.
−53 55	288 10	1834.	FitzRoy.	−23 40	+0 04	−23 36	San Antonio.
−53 49	288 21	1834.	FitzRoy.	−23 50	+0 04	−23 46	Cape Holland.
−54 46	288 23	1834.	FitzRoy.	−24 30	+0 04	−24 26	Cape Desolation.
−52 39	288 29	1834.	FitzRoy.	−23 00	+0 04	−22 56	FitzRoy Passage.
−52 39	288 30	1834.	FitzRoy.	−23 34	+0 04	−23 30	Bennett Point.
−54 56	288 32	1834.	FitzRoy.	−24 15	+0 04	−24 11	Castlereagh Cape.
−55 03	288 37	1834.	FitzRoy.	−24 20	+0 05	−24 15	Nicholson Rocks.
−55 47	288 41	1834.	FitzRoy.	−24 10	+0 05	−24 05	Catherine Island.
−53 54	288 42	1834.	FitzRoy.	−23 20	+0 05	−23 15	Cape Froward.
−54 23	288 43	1834.	FitzRoy.	−23 50	+0 05	−23 45	King Island.
−54 59	288 50	1834.	FitzRoy.	−24 16	+0 05	−24 11	Doris Cove.
−54 24	288 52	1834.	FitzRoy.	−24 57	+0 05	−24 52	Warping Cove.
−55 04	288 52	1834.	FitzRoy.	−24 16	+0 05	−24 11	Hat Isle.
−54 24	288 53	1834.	FitzRoy.	−24 00	+0 05	−23 55	Tarn Cape.
−57 35	288 54	Apr. 1842.	Crozier.	−25 16	−0 02	−25 18	At sea†.
−55 08	288 58	1834.	FitzRoy.	−24 15	+0 05	−24 10	Treble Island.
−53 47	289 02	1834.	FitzRoy.	−23 40	+0 06	−23 34	Cape San Isidoro.
−53 21	289 02	1834.	FitzRoy.	−23 26	+0 06	−23 20	Point St. Mary.
−53 38	289 02	1834.	FitzRoy.	−23 40	+0 06	−23 34	Port Famine Observatory.
−53 38	289 05	1834.	FitzRoy.	−23 00	+0 06	−22 54	Point Santa Anna.
−52 55	289 12	1834.	FitzRoy.	−23 30	+0 06	−23 24	Porpoise Point.
−52 47	289 14	1834.	FitzRoy.	−23 29	+0 06	−23 23	Packet Harbour.
−53 44	289 17	1834.	FitzRoy.	−23 20	+0 06	−23 14	Quoin Head.
−52 42	289 23	1834.	FitzRoy.	−23 50	+0 06	−23 44	Oazy Harbour.
−52 49	289 23	1834.	FitzRoy.	−22 50	+0 06	−23 44	Elizabeth Island.
−52 50	289 25	1834.	FitzRoy.	−23 58	+0 06	−23 52	Santa Martha Island.
−54 54	289 31	1833.	FitzRoy.	−24 14	+0 06	−24 08	Stewart Harbour.
−53 20	289 32	1834.	FitzRoy.	−23 00	+0 06	−22 54	Cape Monmouth.
−53 01	289 33	1834.	FitzRoy.	−23 00	+0 06	−22 54	Point Gente Grande.
−52 56	289 37	1834.	FitzRoy.	−23 20	+0 06	−23 14	Quarter-Master Island.
−53 27	289 47	1834.	FitzRoy.	−23 20	+0 06	−23 14	Cape Bongainville.
−52 39	289 47	June 1834.	FitzRoy.	−23 30	+0 06	−23 24	Gregory Bay.
−50 11	289 50	Apr. 1834.	FitzRoy.	−21 00	+0 06	−20 54	Junction of Chalia Stream with Santa Cruz.
−55 22	289 51	1834.	FitzRoy.	−24 10	+0 06	−24 04	Mary Point.
−52 45	289 52	Jan. 1834.	FitzRoy.	−23 38	+0 06	−23 32	At sea.
−55 23	290 00	1834.	FitzRoy.	−24 04	+0 06	−23 58	March Harbour.
−55 27	290 12	1834.	FitzRoy.	−24 00	+0 06	−23 54	Nativity Cape.
−55 24	290 15	1834.	FitzRoy.	−23 50	+0 06	−23 44	Broken Mount.
−52 37	290 15	1834.	FitzRoy.	−22 40	+0 06	−22 34	St Philip's Bay.
−58 58	290 19	Mar. 1837.	Du Petit-Thouars.	−25 38	+0 03	−25 35	At sea.

TABLE XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −50° and −60° (continued).							
−52 27	290 32	1834.	FitzRoy.	−22 30	+0 06	−22 24	Orange Cape.
−52 15	290 36	1834.	FitzRoy.	−22 40	+0 06	−22 34	Magalhaens Strait.
−55 51	290 40	1834.	FitzRoy.	−24 10	+0 06	−24 04	Ildefonso Isles.
−53 23	290 52	Feb. 1834.	FitzRoy.	−24 40	+0 10	−24 30	At sea.
−50 56	290 54	1834.	FitzRoy.	−21 30	+0 11	−21 19	Coy Inlet.
−50 51	290 55	1834.	FitzRoy.	−21 30	+0 11	−21 19	Redondo Cape.
−54 26	290 57	1834.	FitzRoy.	−22 50	+0 08	−22 42	Admiralty Sound.
−51 33	291 01	1834.	FitzRoy.	−21 47	+0 11	−21 36	Gallegos River.
−55 36	291 02	1834.	FitzRoy.	−24 00	+0 08	−23 52	Mount Beaufoy.
−52 26	291 03	1833.	FitzRoy.	−22 30	+0 13	−22 17	Magalhaens Strait.
−51 36	291 04	Jan. 1845.	Sulivan.	−21 54	−0 10	−22 04	Gallegos River.
−52 17	291 04	Jan. 1834.	FitzRoy.	−22 40	+0 12	−22 28	Cape Possession.
−51 32	291 05	1833.	FitzRoy.	−22 00	+0 13	−21 47	Cape Fairweather.
−56 28	291 17	Jan. 1833.	FitzRoy.	−24 40	+0 14	−24 26	Diego Ramirez Isles, N. and S. Rocks.
−52 31	291 18	1833.	FitzRoy.	−21 00	+0 13	−20 47	Broken Cliff Peak.
−50 15	291 29	1833.	FitzRoy.	−22 00	+0 13	−21 47	Magalhaens Strait.
−50 08	291 33	Apr. 1834.	FitzRoy.	−20 54	+0 11	−20 43	At sea.
−52 24	291 35	1833.	FitzRoy.	−22 36	+0 13	−22 23	Dungeness Point.
−50 07	291 37	1833.	FitzRoy.	−20 54	+0 13	−20 41	Keel Point.
−52 20	291 38	May 1834.	FitzRoy.	−22 30	+0 11	−22 19	Virgin's Cape.
−50 09	291 40	1833.	FitzRoy.	−22 54	+0 13	−22 41	Entrance Mount.
−55 35	291 31	Feb. 1834.	FitzRoy.	−23 50	+0 11	−23 39	Middle Cove (Wollaston Island).
−55 01	291 46	1833.	FitzRoy.	−23 40	+0 13	−23 27	Murray Narrow.
−53 19	291 50	Feb. 1834.	FitzRoy.	−22 40	+0 11	−22 29	Cape San Sebastian.
−55 05	291 53	1833.	FitzRoy.	−23 45	+0 13	−23 32	Button Island.
−55 43	291 54	1833.	FitzRoy.	−23 56	+0 13	−23 43	False Cape Horn.
−55 16	291 54	1833.	FitzRoy.	−23 40	+0 13	−23 27	Cape Webley.
−52 07	291 55	Jan. 1834.	FitzRoy.	−21 40	+0 12	−21 28	At sea.
−55 24	291 56	Feb. 1833.	FitzRoy.	−23 50	+0 13	−23 37	Pack Saddle Island.
−55 31	291 57	1833.	FitzRoy.	−23 56	+0 13	−23 43	Orange Bay.
−50 05	291 57	Apr. 1834.	FitzRoy.	−20 54	+0 11	−20 43	Port Santa Cruz.
−55 40	292 01	1834.	FitzRoy.	−23 30	+0 10	−23 20	Lort Point.
−55 19	292 03	1834.	FitzRoy.	−23 50	+0 10	−23 40	Vauverlandt Islet.
−53 40	292 04	1834.	FitzRoy.	−22 50	+0 10	−22 40	Sunday Cape.
−55 50	292 06	1834.	FitzRoy.	−24 20	+0 10	−24 10	West Point.
−53 15	292 09	Feb. 1834.	FitzRoy.	−24 12	+0 10	−24 02	At sea.
−55 55	292 22	Dec. 1832.	FitzRoy.	−24 30	+0 15	−24 15	Cape Spencer.
−55 51	292 26	Oct. 1842.	Ross.	−23 41	−0 05	−23 46	St. Martin's Cove.
−55 51	292 26	Dec. 1832.	FitzRoy.	−24 23	+0 15	−24 08	St. Martin's Cove.
−53 51	292 27	Dec. 1832.	FitzRoy.	−22 00	+0 15	−21 45	Cape Peñas.
−52 16	292 30	May 1834.	FitzRoy.	−22 22	+0 10	−22 12	At sea.
−54 54	292 32	1834.	FitzRoy.	−23 00	+0 10	−22 50	Clay Cliff Narrow.
−55 34	292 40	1834.	FitzRoy.	−23 45	+0 10	−23 35	Cape de Roos.
−56 00	292 44	Sept. 1842.	Ross.	−24 38	−0 05	−24 43	At sea†.
−55 59	292 44	1834.	FitzRoy.	−24 00	+0 11	−23 49	Cape Horn.
−54 00	292 45	Feb. 1834.	FitzRoy.	−23 05	+0 11	−22 54	At sea.
−53 18	292 45	1834.	FitzRoy.	−22 00	+0 11	−21 49	
−52 39	292 46	Dec. 1832.	FitzRoy.	−21 31	+0 15	−21 16	
−56 07	292 53	Nov. 1842.	Crozier.	−19 58	−0 05	−20 03	At sea†.
−55 18	292 54	Jan. 1833.	FitzRoy.	−23 25	+0 16	−23 09	Goree Road.
−55 05	292 59	1834.	FitzRoy.	−23 20	+0 13	−23 07	Cape Rees.
−55 56	293 01	1834.	FitzRoy.	−23 30	+0 13	−23 17	Deceit Islets.
−52 06	293 02	Dec. 1832.	FitzRoy.	−21 35	+0 16	−21 16	At sea.
−55 23	293 04	1834.	FitzRoy.	−23 42	+0 14	−23 28	Terhalten Island.
−57 09	293 07	May 1836.	Vaillant.	−22 35	+0 09	−22 26	At sea.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −50° and −60° (continued).							
−55° 18′	293° 13′	1834.	FitzRoy.	−23° 40′	+0° 14′	−23° 26′	Lennox Harbour.
−55 48	293 15	1834.	FitzRoy.	−23 00	+0 14	−22 46	Barnevelt.
−55 17	293 24	1834.	FitzRoy.	−23 30	+0 14	−23 16	Fifty Point.
−55 48	293 37	Feb. 1834.	FitzRoy.	−23 31	+0 15	−23 16	At sea.
−54 57	294 13	1834.	FitzRoy.	−22 50	+0 14	−22 36	Aguirre Bay.
−50 42	294 15	Dec. 1832.	FitzRoy.	−20 41	+0 18	−20 23	At sea.
−56 46	294 30	Apr. 1842.	Crozier.	−20 26	−0 06	−20 32	At sea†.
−56 49	294 31	May 1836.	Vaillant.	−24 11	+0 09	−24 02	At sea.
−54 39	294 46	Dec.1832 and Feb.1834	FitzRoy.	−22 50	+0 19	−22 31	Cape San Vicente.
−51 18	294 46	Dec. 1832.	FitzRoy.	−20 26	+0 19	−20 07	At sea.
−54 48	294 46	Dec. 1832.	FitzRoy.	−22 48	+0 19	−22 29	Good Success Bay.
−54 41	294 53	1834.	FitzRoy.	−22 50	+0 15	−22 35	Cape San Diego.
−54 48	295 15	1834.	FitzRoy.	−22 00	+0 15	−21 45	Middle Cape.
−54 54	295 15	1834.	FitzRoy.	−22 40	+0 15	−22 25	Cape St. Bartholomew.
−54 53	295 18	1828.	Foster.	−20 32	+0 32	−20 00	Franklin Bay.
−54 48	295 19	1828.	Foster.	−23 33	+0 32	−23 01	Crossley Bay.
−55 42	295 20	Nov. 1842.	Crozier.	−24 19	−0 08	−24 27	At sea†.
−55 39	295 23	Nov. 1842.	Ross.	−23 41	−0 08	−23 49	At sea†.
−54 47	295 27	1828.	Foster.	−21 13	+0 32	−20 41	Flinders Bay.
−53 54	295 32	Mar. 1837.	Du Petit-Thouars.	−20 10	+0 07	−20 03	At sea (2).
−54 49	295 38	1828.	Foster.	−21 43	+0 32	−21 11	Port Parry.
−54 42	295 42	1834.	FitzRoy.	−22 30	+0 15	−22 15	Cape Colnett.
−50 15	295 45	Apr. 1834.	FitzRoy.	−19 52	+0 15	−19 37	At sea.
−54 50	295 47	1828.	Foster.	−22 26	+0 32	−21 54	Grant Bay.
−54 39	295 54	1834.	FitzRoy.	−22 30	+0 15	−22 15	New Year Islands.
−54 46	295 57	1834.	FitzRoy.	−22 30	+0 15	−22 15	Port Cook.
−54 46	295 58	1828.	Foster.	−22 15	+0 32	−21 43	Observatory.
−54 43	296 17	1828.	Foster.	−22 30	+0 32	−21 58	Cape St. John.
−51 57	296 36	Mar. 1837.	Du Petit-Thouars.	−20 16	+0 07	−20 09	At sea.
−55 41	296 47	Sept. 1842.	Crozier.	−24 12	−0 07	−24 19	At sea†.
−53 47	297 01	May 1836.	Vaillant.	−19 56	+0 16	−19 46	At sea.
−50 56	297 04	May 1836.	Vaillant.	−20 38	+0 10	−20 28	At sea.
−50 44	297 17	Mar. 1837.	Du Petit-Thouars.	−19 28	+0 08	−19 20	At sea.
−51 43	298 43	1834.	FitzRoy.	−20 18	+0 20	−19 58	Ship Harbour, Falklands.
−51 42	298 43	Jan. 1845.	Sulivan.	−19 29	−0 19	−19 48	New Island, Falklands.
−52 01	299 00	Feb. 1845.	Sulivan.	−19 58	−0 19	−20 17	Reef Harbour.
−55 29	299 03	Oct 1842.	Ross.	−24 33	−0 11	−24 44	At sea†.
−55 32	299 12	Oct. 1842.	Ross.	−21 46	−0 11	−21 57	At sea†.
−52 12	299 18	1834.	FitzRoy.	−20 24	+0 19	−20 05	Stephen's Port, Falklands.
−51 21	299 21	Jan. 1844.	Sulivan.	−18 29	−0 14	−18 43	Hope Harbour, Falklands.
−51 32	299 31	Nov. 1844.	Sulivan.	−19 07	−0 17	−19 24	Whale Cove.
−52 03	299 44	1834.	FitzRoy.	−20 00	+0 17	−19 43	Port Edgar.
−54 32	299 53	Oct. 1842.	Crozier.	−22 30	−0 09	−22 39	At sea†.
−51 21	299 56	1834.	FitzRoy.	−19 35	+0 17	−19 18	Port Egmont, Falklands.
−51 21	299 56	Apr. 1844.	Sulivan.	−18 47	−0 14	−19 01	At sea†.
−54 53	299 59	Oct. 1842.	Ross.	−21 19	−0 09	−21 28	At sea†.
−52 21	300 15	Feb. 1844.	Sulivan.	−18 35	−0 13	−18 48	Owen Road, Falklands.
−55 58	300 16	Apr. 1830.	Erman.	−19 41	+0 30	−19 11	At sea.
−55 07	300 19	Sept. 1842.	Crozier.	−21 56	−0 09	−22 05	At sea†.
−51 20	300 30	Apr. 1844.	Sulivan.	−18 20	−0 15	−18 35	Tamar Harbour, Falklands.
−52 09	300 35	Feb. 1844.	Sulivan.	−18 18	−0 15	−18 33	Bay of Islands.
−52 21	300 40	1834.	FitzRoy.	−19 50	+0 17	−19 33	Bull Road.
−52 22	300 41	1834.	FitzRoy.	−19 42	+0 17	−19 25	Porpoise Point.
−53 04	300 51	Nov. 1842.	Ross.	−19 57	−0 09	−20 06	At sea†.

Table XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −50° and −60° (continued).							
−52° 12	300° 56	1834.	FitzRoy.	−19° 36	+0° 18	−19° 12	Adventure Sound.
−51 33	300 57	Nov. 1844.	Sulivan.	−17 56	−0 16	−18 12	Port San Carlos, Falklands.
−52 16	301 06	April 1842.	Ross.	−16 29	−0 09	−16 38	At sea.
−52 14	301 09	April 1842.	Crozier.	−18 25	−0 09	−18 36	At sea.
−54 43	301 12	Nov. 1842.	Crozier.	−21 29	−0 09	−21 38	At sea.
−52 01	301 22	Dec. 1843.	Sulivan.	−18 14	−0 15	−18 29	Seal Cove, Falklands.
−51 48	301 50	July 1844.	Sulivan.	−16 52	−0 18	−17 10	Pleasant Island.
−51 31	301 51	Mar. 1843.	Sulivan.	−17 26	−0 13	−17 39	Port Louis, Old Settlement.
−51 31	301 53	Jan. 1844.	Sulivan.	−17 16	−0 16	−17 32	Port Louis.
−51 22	301 53	Aug. 1842.	Ross.	−17 36	−0 10	−17 46	Port Louis.
−51 32	301 53	1834.	FitzRoy.	−19 00	+0 21	−18 39	Port Louis.
−51 30	302 06	Mar. 1833.	FitzRoy.	−18 43	+0 24	−18 19	At sea.
−51 35	302 10	1834.	FitzRoy.	−19 00	+0 22	−18 38	Berkeley Sound, Falklands.
−51 41	302 10	Nov. 1844.	Sulivan.	−17 18	−0 19	−17 37	Stanley Harbour.
−52 04	302 47	Dec. 1842.	Ross.	−17 49	−0 11	−18 00	At sea†.
−52 54	302 57	Sept. 1842.	Crozier.	−21 38	−0 11	−21 49	At sea†.
−52 46	303 12	Dec. 1842.	Crozier.	−19 18	−0 11	−19 29	At sea†.
−52 50	303 12	Dec. 1842.	Ross.	−18 20	−0 11	−18 31	At sea†.
−56 53	303 21	May 1846.	Bérard.	−18 16	−0 25	−18 31	At sea.
−55 05	303 22	Sept. 1830.	Erman.	−18 58	+0 30	−18 28	At sea.
−53 50	303 49	Dec. 1842.	Crozier.	−19 57	−0 11	−20 08	At sea†.
−53 56	303 52	Dec. 1842.	Ross.	−17 20	−0 11	−17 31	At sea†.
−53 55	304 18	Sept. 1842.	Ross.	−18 12	−0 08	−18 20	At sea†.
−54 05	304 26	Sept. 1842.	Crozier.	−20 49	−0 08	−20 57	At sea†.
−54 12	305 15	Sept. 1842.	Crozier.	−17 03	−0 08	−17 11	At sea†.
−55 45	305 17	Dec. 1842.	Crozier.	−19 43	−0 08	−19 51	At sea†.
−55 46	305 17	Dec. 1842.	Ross.	−18 40	−0 09	−18 49	At sea†.
−55 15	305 39	May 1846.	Bérard.	−17 19	−0 20	−17 39	At sea.
−54 33	306 13	May 1846.	Bérard.	−14 14	−0 20	−14 34	At sea.
−56 36	306 38	Dec. 1842.	Ross.	−17 35	−0 09	−17 44	At sea†.
−56 54	306 41	Dec. 1842.	Crozier.	−19 13	−0 09	−19 22	At sea†.
−58 25	308 00	Dec. 1842.	Crozier.	−17 44	−0 09	−17 53	At sea†.
−58 29	308 13	Dec. 1842.	Ross.	−17 45	−0 09	−17 54	At sea†.
−59 28	308 20	Dec. 1842.	Crozier.	−21 05	−0 09	−21 14	At sea†.
−59 54	308 28	Dec. 1842.	Ross.	−17 49	−0 09	−17 58	At sea†.
−52 52	309 34	May 1846.	Bérard.	−14 02	−0 20	−14 22	At sea.
−57 30	351 40	Mar. 1843.	Crozier.	+10 29	−0 25	+10 04	At sea†.
−57 33	352 04	Mar. 1843.	Ross.	12 11	−0 25	11 46	At sea†.
−57 16	352 52	Mar. 1843.	Crozier.	11 11	0 25	10 46	At sea†.
−57 06	352 53	Mar. 1843.	Ross.	13 06	−0 25	12 41	At sea†.
−56 12	354 46	Mar. 1843.	Crozier.	12 05	−0 25	11 40	At sea†.
−56 15	354 56	Mar. 1843.	Ross.	13 13	−0 25	12 48	At sea†.
−54 11	359 08	Mar. 1843.	Ross.	16 58	−0 25	16 33	At sea†.
−54 18	359 38	Mar. 1843.	Crozier.	14 39	−0 25	14 14	At sea.
−59 02	4 09	Jan. 1845.	Moore and Clerk.	17 30	−0 45	16 45	At sea†.
−55 29	5 54	Jan. 1845.	Moore and Clerk.	21 23	−0 45	20 38	At sea†.
−53 52	6 12	Jan. 1845.	Moore and Clerk.	21 24	−0 45	20 39	At sea†.
−52 56	7 53	Jan. 1845.	Moore and Clerk.	23 46	−0 45	23 01	At sea†.
−51 47	9 34	Jan. 1845.	Moore and Clerk.	23 37	−0 45	22 52	At sea†.
−50 45	10 18	Jan. 1845.	Moore and Clerk.	23 55	−0 45	23 10	At sea†.
Between the latitudes of −60° and −70°.							
−64 40	302 07	Jan. 1843.	Crozier.	−24 07	0 00	−24 07	At sea†.
−64 39	302 36	Jan. 1843.	Ross.	−22 14	0 00	−22 14	At sea†.

TABLE XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −60° and −70° (continued).							
−64° 40′	302° 40′	Jan. 1843.	Crozier.	−24° 05′	0° 00′	−24° 05′	At sea†.
−64 38	302 49	Jan. 1843.	Ross.	−23 03	0 00	−23 03	At sea†.
−64 41	302 52	Jan. 1843.	Crozier.	−23 52	0 00	−23 52	At sea†.
−64 32	302 55	Jan. 1843.	Crozier.	−23 38	0 00	−23 38	At sea†.
−64 19	303 03	Jan. 1843.	Ross.	−21 53	0 00	−21 53	At sea†.
−64 44	303 10	Jan. 1843.	Ross.	−21 13	0 00	−21 13	At sea†.
−64 44	303 10	Jan. 1843.	Ross.	−21 48	0 00	−21 48	At sea†.
−64 20	303 12	Jan. 1843.	Crozier.	−23 45	0 00	−23 45	At sea†.
−64 38	303 30	Jan. 1843.	Crozier.	−23 05	0 00	−23 05	At sea†.
−64 31	303 38	Jan. 1843.	Ross.	−22 53	0 00	−22 53	At sea†.
−64 05	303 47	Jan. 1843.	Ross.	−22 05	0 00	−22 05	At sea†.
−64 15	303 49	Jan. 1843.	Ross.	−21 07	0 00	−21 07	At sea†.
−64 11	303 50	Jan. 1843.	Crozier.	−22 43	0 00	−22 43	At sea†.
−64 26	303 52	Jan. 1843.	Ross.	−22 44	0 00	−22 44	At sea†.
−64 05	303 55	Jan. 1843.	Crozier.	−22 21	0 00	−22 21	At sea†.
−64 23	304 00	Jan. 1843.	Ross.	−22 43	+0 03	−22 40	At sea†.
−64 06	304 03	Jan. 1843.	Ross.	−21 10	+0 03	−21 07	At sea†.
−64 16	304 05	Jan. 1843.	Ross.	−22 25	+0 03	−22 22	At sea†.
−64 33	304 05	Jan. 1843.	Crozier.	−22 23	+0 03	−22 20	At sea†.
−64 24	304 10	Jan. 1843.	Ross.	−21 10	+0 03	−21 07	At sea†.
−64 04	304 11	Jan. 1843.	Crozier.	−22 40	+0 03	−22 37	At sea†.
−64 17	304 17	Jan. 1843.	Crozier.	−22 22	+0 03	−22 19	At sea†.
−64 04	304 18	Jan. 1843.	Ross.	−21 02	+0 03	−20 59	At sea†.
−64 19	304 20	Jan. 1843.	Ross.	−21 36	+0 03	−21 33	At sea†.
−64 00	304 22	Jan. 1843.	Crozier.	−22 54	+0 03	−22 51	At sea†.
−63 47	304 31	Dec. 1842.	Crozier.	−22 19	+0 03	−22 16	At sea†.
−64 17	304 42	Jan. 1843.	Crozier.	−21 51	+0 03	−21 48	At sea†.
−64 01	305 00	Feb. 1843.	Ross.	−21 01	+0 03	−20 58	At sea†.
−63 49	305 00	Dec. 1842.	Ross.	−22 27	+0 03	−22 24	At sea†.
−64 03	305 18	Jan. 1843.	Crozier.	−22 02	+0 03	−21 59	At sea†.
−64 12	305 20	Feb. 1843.	Crozier.	−21 51	+0 03	−21 48	At sea†.
−62 54	305 41	Dec. 1842.	Ross.	−20 52	−0 02	−20 54	At sea†.
−64 20	306 00	Jan. 1843.	Crozier.	−21 40	+0 02	−21 38	At sea†.
−62 39	306 12	Dec. 1842.	Crozier.	−21 30	−0 02	−21 32	At sea†.
−62 00	307 52	Dec. 1842.	Crozier.	−20 25	−0 02	−20 27	At sea†.
−62 18	308 03	Dec. 1842.	Ross.	−19 03	−0 02	−19 05	At sea†.
−62 20	308 12	Dec. 1842.	Crozier.	−21 21	−0 02	−21 23	At sea†.
−64 10	309 30	Feb. 1843.	Crozier.	−19 14	−0 02	−19 16	At sea†.
−64 41	316 00	Feb. 1843.	Crozier.	−15 43	−0 06	−15 49	At sea†.
−64 36	316 05	Feb. 1843.	Ross.	−13 41	−0 06	−13 47	At sea†.
−64 50	316 40	Feb. 1843.	Crozier.	−15 01	−0 06	−15 07	At sea†.
−64 38	316 57	Feb. 1843.	Ross.	−13 32	−0 06	−13 38	At sea†.
−64 04	318 29	Feb. 1843.	Crozier.	−13 59	−0 10	−14 09	At sea†.
−65 06	318 57	Feb. 1843.	Ross.	−12 49	−0 10	−12 59	At sea†.
−63 58	321 43	Feb. 1843.	Crozier.	−10 13	−0 16	−10 29	At sea†.
−63 57	322 00	Feb. 1843.	Ross.	− 9 11	−0 16	− 9 27	At sea†.
−62 38	328 00	Feb. 1843.	Crozier.	− 7 30	−0 16	− 7 46	At sea†.
−62 41	328 27	Feb. 1843.	Ross.	− 6 09	−0 16	− 6 25	At sea†.
−62 20	330 30	Feb. 1843.	Ross.	− 4 41	−0 16	− 4 57	At sea†.
−62 09	332 38	Feb. 1843.	Crozier.	− 3 43	−0 16	− 3 59	At sea†.
−62 06	333 43	Feb. 1843.	Ross.	− 3 48	−0 25	− 4 13	At sea†.
−62 00	333 44	Feb. 1843.	Crozier.	− 2 42	−0 25	− 3 07	At sea†.
−61 55	333 48	Feb. 1843.	Ross.	− 3 41	−0 25	− 4 06	At sea†.
−61 32	335 33	Feb. 1843.	Crozier.	− 0 34	−0 25	− 0 59	At sea†.
−61 36	336 20	Feb. 1843.	Ross.	− 0 42	−0 25	− 1 07	At sea†.
−70 43	343 12	Mar. 1843.	Crozier.	2 01	−0 23	1 38	At sea†.

TABLE XII. (Continued.)

Lat.	Long.	Date.	Observer.	Observed Declination.	Correction for Epoch.	Corrected Declination.	Remarks.
Between the latitudes of −60° and −70° (continued).							
−70° 50′	343° 34′	Mar. 1843.	Ross.	3° 03′	−0° 23′	2° 40′	At sea†.
−62 18	343 44	Feb. 1843.	Crozier.	3 01	−0 25	2 36	At sea†.
−62 24	343 58	Feb. 1843.	Crozier.	5 00	−0 25	4 35	At sea†.
−62 52	344 33	Feb. 1843.	Ross.	4 49	−0 25	4 24	At sea†.
−64 48	345 16	Feb. 1843.	Ross.	5 11	−0 25	4 46	At sea†.
−69 42	345 20	Mar. 1843.	Crozier.	1 35	−0 23	1 12	At sea†.
−69 13	345 55	Mar. 1843.	Ross.	3 25	−0 23	3 02	At sea†.
−64 29	346 02	Mar. 1843.	Ross.	4 19	−0 25	3 54	At sea†.
−64 06	346 15	Mar. 1843.	Crozier.	5 15	−0 25	4 50	At sea†.
−64 14	346 15	Feb. 1843.	Crozier.	5 01	−0 25	4 36	At sea†.
−66 10	346 40	Mar. 1843.	Crozier.	5 25	−0 25	5 00	At sea†.
−68 30	346 50	Mar. 1843.	Crozier.	3 51	−0 25	3 26	At sea†.
−68 10	347 45	Mar. 1843.	Crozier.	5 18	−0 25	4 53	At sea†.
−68 08	348 10	Mar. 1843.	Crozier.	3 48	−0 25	3 23	At sea†.
−61 16	348 56	Mar. 1843.	Ross.	8 49	−0 25	8 24	At sea†.
−61 16	349 00	Mar. 1843.	Crozier.	7 07	−0 25	6 42	At sea†.
−65 01	349 04	Feb. 1843.	Crozier.	6 34	−0 25	6 09	At sea†.
−65 08	349 50	Feb. 1843.	Ross.	7 35	−0 25	7 10	At sea†.
−67 12	350 36	Mar. 1843.	Crozier.	6 43	−0 25	6 18	At sea†.
−66 00	351 00	Mar. 1843.	Crozier.	8 47	−0 25	8 22	At sea†.
−66 40	351 39	Mar. 1843.	Ross.	8 54	−0 25	8 29	At sea†.
−61 12	9 30	Feb. 1845.	Moore and Clerk.	20 29	−0 40	19 49	At sea†.
−62 03	12 45	Feb. 1845.	Moore and Clerk.	22 07	−0 40	21 27	At sea†.
−61 54	16 40	Feb. 1845.	Moore and Clerk.	23 11	−0 40	22 31	At sea†.
−61 49	19 13	Feb. 1845.	Moore and Clerk.	26 16	−0 40	25 36	At sea†.
−62 05	20 58	Feb. 1845.	Moore and Clerk.	28 05	−0 40	27 25	At sea†.

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XIII. *Contributions to the Chemistry of the Urine.*—Paper III.

PART I. *On the Variations of the Acidity of the Urine in the state of Health.*

PART II. *On the simultaneous Variations of the amount of Uric Acid, and the Acidity of the Urine in the state of Health.*

PART III. *On the Variations of the Sulphates in the state of Health, and on the influence of Sulphuric Acid, Sulphur and Sulphates, on the amount of Sulphates in the Urine.*

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Received November 20, 1848,—Read January 25, 1849.

PART I.—*On the Variations of the Acidity of the Urine in the state of Health.*

IN the Philosophical Transactions for 1845, I showed that not unfrequently in London, the urine was found in many persons to be alkaline from fixed alkali; and I mentioned that Dr. ANDREWS, at Belfast, had found the water passed at noon of two-thirds of the students of his class to be alkaline.

It appeared to me to be a matter of great interest to determine quantitatively the daily variations in the acidity and alkalescence of the urine in the state of health; to trace, if possible, the cause of the variations; to determine the effect of some medicines; at the least until this was done I could draw no conclusions regarding the effect of diseases on the acidity of the urine.

In examining quantitatively the variations at different hours of the day, it was immediately found that there was no fixed degree of acidity of the urine; that the acidity did not vary with the specific gravity, but that there was a never-ceasing change, an ebb and flow, in the acid reaction of the urine, which was quite independent of the specific gravity.

The degree of acidity of the urine was found generally to be greatest a short time before food was taken; and after food the acidity was diminished, until about three hours after breakfast, and four or five, or six hours after dinner, when it reached the minimum point; after which it again rose and attained its height previous to food being again taken.

A healthy man was the subject of the following experiments: for three months he had taken strong exercise, walking above 700 miles. Food was taken twice daily. The exercise was moderate during the experiments, from three to four hours daily.

The urine not unfrequently showed most marked alkalescence from fixed alkali. Rarely even phosphate of lime was deposited. Five or six hours afterwards the

acidity reached its highest point, but did not on any occasion cause the formation of uric acid crystals.

The mode of examination was the following. Two test solutions were made, the one with carbonate of soda, the other with dilute sulphuric acid. Each measure of either test was made equivalent to $\frac{1}{12}$th of a grain of dry and pure carbonate of soda.

A bottle containing 1000 grains at least of urine was filled and weighed. The urine was heated in a cup to 120°, and then the test solution was dropped in from a graduated tube; so that the urine, when acid, was made, by alkali, just neutral to the most delicate test-paper; and when alkaline, it was made just neutral by acid. The number of measures required gave the degree of acidity or alkalescence of the urine.

In the second part of this paper, it will be seen from experiments made four months previously to these, that the same kind of variations took place then; and in the same case two years before, and again even three years previous to these experiments, the same fact was noted.

Thus, October 13, 1846, breakfast on bread and meat at 9 A.M.

Urine passed at 1 P.M., clear. Specific gravity . . 1022·8. Alkaline.
Urine passed at 3 P.M., clear. Specific gravity . . 1019·9. Acid.

And October 28, 1845, breakfast at $9^h\ 15^m$.

	h	m		
Urine passed at	10		A.M.	Acid.
Urine passed at	12	30	P.M.	Alkaline.
Urine passed at	3			Acid.

(1.) October 14, 1848. Breakfast on bread, meat and coffee, at $8^h\ 45^m$ A.M. Dinner at $5^h\ 50^m$ P.M. Fish, meat, potatoes and water.

	h	m		Spec. gr.	Acidity per 1000 grs. of urine.	Appearances.
Water passed at	7	15	A.M.	thrown away.		
Water passed at	8	45		=1021·1	+11·75 measures.	Clear.
Water passed at	9	55		=1023·5	+ 8·79	Clear.
Water passed at	11	15		=1022·7	−11·73	Clear.
Water passed at	12			=1024·4	−29·28	Thick from phosphates.
Water passed at	12	50	P.M.	=1024·0	−10·74	Clear.
Water passed at	2	15		=1021·5	+ 6·85	Clear.
Water passed at	3	50		=1024·1	+15·62	Clear.
Water passed at	5	50		=1024·4	+21·47	Clear.
Water passed at	7	55		=1029·6	+15·54	Thick from urates.
Water passed at	10	45		=1029·8	− 5·82	Clear.
Water passed at	6	30	A.M.	=1023·3	+ 9·77	Clear.
Water passed at	7	40		=1025·3	+13·65	Clear.

(2.) Breakfast at $8^h\ 45^m$ A.M., the same as the day previous. Dinner the same, at $5^h\ 45^m$ P.M.

Water passed at	8	45	=1025·6	+15·60 measures.	Clear.
Water passed at	10		=1021·3	+11·74	Clear.

	h	m	Spec. gr.	Acidity per 1000 grs. of urine.	Appearances.
Water passed at	11	20 A.M.	=1024·9	−12·68 measures.	Clear.
Water passed at	12	20 P.M.	=1029·2	−14·57	Thick from phosphates.
Water passed at	12	45			Clear.
Water passed at	3	15	=1028·4	+13·61	Clear.
Water passed at	5	45	=1026·6	+22·40	Clear.
Water passed at	9		=1032·9	+13·55	Thick from urates.
Water passed at	11	10	=1030·4	+ 3·88	Clear.
Water passed at	2	30 A.M.	=1011·4	+ 5·93	Clear.
Water passed at	7	30	=1020·6	+11·75	Clear.

(3.) Breakfast at $8^h\ 45^m$ A.M., the same as the day previous. Dinner at $5^h\ 5^m$ P.M.

Water passed at	8	45	=1024·8	+19·51 measures.	Thick urates.
Water passed at	9	50	=1020·6	+12·73	Clear.
Water passed at	10	50	=1021·8	+ 1·95	Clear.
Water passed at	12	50 P.M.	=1027·2	− 1·94	Clear.
Water passed at	2	50	=1024·7	+10·73	Clear.
Water passed at	5	5	=1024·9	+18·53	Clear.
Water passed at	7	35	=1029·2	+15·54	Thick from urates.
Water passed at	10	5	=1027·2	− 7·78	Clear.
Water passed at	2	15 A.M.	=1022·0	+ 8·80	Clear.
Water passed at	6	45	=1024·6	+16·59	Clear.
Water passed at	7	45	=1024·8	+20·49	Thick from urates.
Water passed at	8	45	=1022·5	+13·69	Clear.

From these experiments, which lasted three days, it appears that before each meal the urine showed the highest degree of acidity; and the water passed two or three hours after food always showed a lower degree of acidity than that made before food. The decrease continued until three hours after breakfast, and five or six hours after dinner, when it reached the lowest point. The acidity of the urine then increased until just before food, when it again reached the highest limit.

Thus, when breakfast was taken at half-past eight, the acidity of 1000 grains of the urine then passed was sufficient to neutralize about one grain of dry and pure carbonate of soda. At twelve o'clock the urine was as alkaline as if every 1000 grains of urine contained two and a half grains of carbonate of soda. At half-past five, just before dinner, the acidity had increased, so that every 1000 grains of urine was so acid as to require two grains of carbonate of soda to neutralize it. At half-past ten the acidity had diminished, so that every 1000 grains of urine was as alkaline as if they contained half a grain of carbonate of soda. After this it probably became more alkaline, and then still longer after food became acid; and by half-past eight in the morning, each 1000 grains of urine required about a grain and one-third of carbonate of soda to neutralize the acid reaction.

The same changes were observed on each of the two following days. These varia-

tions are seen in the accompanying Plate XVI. better than they can be set forth in words, and the influence of digestion on the acidity of the urine is made evident.

There is a slight exception which requires notice. In the last day, before breakfast, at $6^h\ 45^m$ A.M., the specific gravity was 1024·6, and every 1000 grains had an acidity marked by 16·59 measures. At $7^h\ 45^m$ P.M. the acidity had increased to 20·45, the specific gravity having hardly changed. At $8^h\ 45^m$ A.M., just before breakfast, the acidity had decreased to 13·69, with a very slight diminution of the specific gravity.

As a test of the truth of the conclusions drawn from the previous experiments, the variations of the acidity were noted when no food was taken in the morning, and the following results were obtained.

(4.) No food was taken from dinner the previous day at $5^h\ 30^m$ P.M., to dinner this day at $5^h\ 10^m$ P.M. Both days the food was meat, soup, potatoes, bread and water. The urine was passed as frequently as possible.

	h	m		Spec. gr.	Acidity per 1000 grs. of urine.	
Water passed at	6	10	A.M.	1025·7	+15·59 measures.	Clear.
Water passed at	7	50	No breakfast.	1028·6	+13·61	Thick from urates.
Water passed at	9	10		1026·3	+15·58	Thick from urates.
Water passed at	11	20		1025·0	+12·68	Thick from urates.
Water passed at	12	30	P.M.	1025·7	+13·64	Thick from urates.
Water passed at	2	45		1028·0	+15·56	Thick from urates.
Water passed at	5	10	Dinner.	1031·3	+15·51	Thick from urates.
Water passed at	7	10		1034·6	+13·53	Thick from urates.
Water passed at	9	5		1029·4	− 7·77	Clear.
Water passed at	11			1029·5	− 2·91	Clear.
Water passed at	5	40	A.M.	1026·9	+10·71	Clear.
Water passed at	8	45	Breakfast.	1028·0	+17·51	Thick from urates.
Water passed at	10	15		1026·3	+ 9·74	Thick from urates.
Water passed at	12	30	P.M.	1028·7	−14·57	Thick from phosphates.
Water passed at	3	10		1028·8	− 0·97	Clear.

Plate XVII. shows these variations, and contrasts the slight changes when breakfast was not taken, with the great changes after food.

From six in the morning until dinner was taken, soon after five, the variations in the acidity of the urine were very small; requiring rather more than one grain of carbonate of soda to neutralize 1000 grains of the urine. Four hours after dinner the urine was so diminished in acidity, that every 1000 grains of urine had an alkaline reaction equal to two-thirds of a grain of dry and pure carbonate of soda. Two hours after this the acidity was found to be increased, and by breakfast time, the following morning, 1000 grains of urine required a grain and a half of carbonate of soda to neutralize their acidity. Four hours after breakfast the acidity had decreased so much, that 1000 grains of urine were as alkaline as if they had contained nearly a grain and a quarter of carbonate of soda.

II. I next endeavoured to determine whether different kinds of food caused different changes in the acidity of the urine. For three days consecutively animal food only was taken at $8^h\ 45^m$ A.M. and $5^h\ 40^m$ P.M. Beefsteaks, eggs, weak coffee, milk and water.

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	h	m		Spec. gr.	Acidity per 1000 grs. of urine.	
(5.) Water passed at	7	0	A.M.	thrown away.		
Water passed at	8	45		1024·6	+ 7·80 measures.	Clear.
Water passed at	9	50		1019·9	− 7·84	Clear.
Water passed at	10	55		1020·2	−30·38	Thick from phosphates.
Water passed at	12	55	P.M.	1025·2	− 9·73	Clear.
Water passed at	3	0		1027·0	+13·63	Thick from urates.
Water passed at	5	40		1029·5	+19·42	Thick from urates.
Water passed at	8	5		1032·8	+14·52	Thick from urates.
Water passed at	10	30		1030·3	0	Thick from urates.
Water passed at	5	0	A.M.	1022·9	+10·75	Clear.
Water passed at	7	10		1026·1	+17·52	Clear.

(6.) Breakfast at $8^h\ 50^m$ A.M. Dinner at $5^h\ 40^m$ P.M. Animal food only; the same as the previous day.

Water passed at	8	50		1026·7	+10·71 measures.	Clear.
Water passed at	10	10		1025·3	+ 1·95	Clear.
Water passed at	11	10		1024·6	−26·35	Thickish from phosphates.
Water passed at	12	30	P.M.	1025·3	−29·26	Thick from phosphates.
Water passed at	1	50		1025·5	− 1·95	Clear.
Water passed at	3	30		1025·0	+ 9·75	Clear.
Water passed at	5	40		1027·4	+17·52	Clear.
Water passed at	7	40		1031·7	+11·63	Thick from urates.
Water passed at	11	0		1028·7	− 2·91	Clear.
Water passed at	7	15	A.M.	1024·6	+13·66	Clear.

(7.) Breakfast at $8^h\ 50^m$ A.M. Dinner at $5^h\ 50^m$ P.M. Animal food only; the same as the previous day.

Water passed at	8	50		1027·0	+15·58 measures.	Thick from urates.
Water passed at	10	8		1026·5	+ 1·94	Cloudy.
Water passed at	11	10		1026·9	−24·34	Thick from phosphates.
Water passed at	12	10	P.M.	1029·8	−26·21	Thick from phosphates.
Water passed at	2	15		1025·2	+ 3·90	Cloudy.
Water passed at	3	40		1028·1	+13·61	Cloudy.
Water passed at	5	55		1029·7	+18·45	Cloudy.
Water passed at	7	55		1035·4	+16·41	Thick.
Water passed at	10	55		1031·7	+ 2·90	Thick.
Water passed at	6	0	A.M.	1026·0	+12·67	Clear.
Water passed at	7	40		1028·6	+18·46	Thick.
Water passed at	8	55		1028·7	+20·41	Thick.

From the comparison of these numbers, as seen in Plate XVIII., with those obtained when a mixed diet was taken, as in Plate XVI., it is apparent,—

1st. That the diminution of the acidity after food is more marked, and continues longer when animal food only is taken, than it does when mixed diet is eaten.

2nd. That the acidity before food rises rather higher with a mixed diet than it does with animal food only.

There is the same exception observable on the second day of animal food as was seen the third day when mixed diet was taken. At ten minutes after seven the urine had an acidity for every 1000 grains marked by 17·52 measures. At fifty minutes after eight (just before breakfast) the acidity was diminished to 10·71 measures. There was but little difference in the specific gravity of the two quantities.

For three days consecutively vegetable food only was taken, twice each day. Breakfast at $8^h\ 55^m$ A.M. Dinner at $6^h\ 15^m$ P.M.

	h m	Spec. gr.	Acidity per 1000 grs. of urine.	
(8.) Water passed at	8 55 A.M.	1028·7	+20·41 measures.	Thick from urates.
Water passed at	10 20	1028·0	+12·64	Thick.
Water passed at	11 40	1027·5	+ 7·78	Thick.
Water passed at	1 0 P.M.	1028·4	+ 7·78	Thick.
Water passed at	2 55	1027·8	+ 8·75	Thick.
Water passed at	6 15	1031·5	+20·36	Thick.
Water passed at	8 20	1036·4	+15·43	Thick.
Water passed at	11 5	1035·3	+16·42	Thick.
Water passed at	3 30 A.M.	1030·1	+12·62	Thick.
Water passed at	7 30	1030·1	+20·38	Thick.

(9.) Breakfast at $8^h\ 50^m$ A.M. Dinner at $5^h\ 35^m$ P.M. Vegetable food only.

Water passed at	8 50	1031·2	+26·18 measures.	Thick.
Water passed at	10 30	1029·4	+ 5·83	Thick.
Water passed at	12 0	1028·9	0	Clear.
Water passed at	2 10 P.M.	1027·8	+ 2·91	Clear.
Water passed at	5 35	1028·5	+16·52	Thick.
Water passed at	8 35	1034·2	+11·60	Thick.
Water passed at	11 45	1012·4	+ 1·97	Clear.
Water passed at	6 45 A.M.	1009·1	+ 5·94	Clear.
Water passed at	8 55	1020·5	+14·69	Clear.

(10.) Breakfast at $8^h\ 55^m$ A.M. Dinner at $5^h\ 55^m$ P.M. Vegetable food only. At breakfast about two ounces of honey were taken.

Water passed at	10 0	1013·5	+ 7·89 measures.	Clear.
Water passed at	10 35	1009·1	+ 4·95	Clear.
Water passed at	11 30	1018·9	+ 4·90	Clear.
Water passed at	12 50 P.M.	1020·8	+ 5·87	Clear.
Water passed at	2 10	1017·9	+ 6·87	Clear.

	h	m		Spec. gr.	Acidity per 1000 grs. of urine.	
Water passed at	3	30	P.M.	1019·8	+ 8·82 measures.	Clear.
Water passed at	5	55		1021·2	+16·64	Clear.
Water passed at	8	30		1030·9	+17·46	Thick from urates.
Water passed at	10	50		1023·4	0	Clear.
Water passed at	6	30	A.M.	1010·6	+ 5·93	Clear.
Water passed at	8	45		1020·9	+ 8·81	Clear.

Breakfast at $8^h\ 45^m$ A.M. on animal food only.

Water passed at	10	20		1023·1	−10·75 measures.	Clear.
Water passed at	11	0		1022·9	−29·23	Thick from phosphates.
Water passed at	12	0		1022·3	−30·75	Thick from phosphates.
Water passed at	12	50	P.M.	1023·5	−25·40	Thick from phosphates.
Water passed at	4	30		1027·6	+13·62	Thick from urates.

If these changes, represented in Plate XIX., are compared with those in Plate XVIII., it will be evident that the diminution of the acidity of the urine is very different, though the experiments were made on six consecutive days. For the three days that vegetable food was taken, the urine never was markedly alkaline; twice it was neutral to test-paper, between three and four hours after breakfast; but it never became so alkaline as when the diet was mixed, or consisted of animal food only. The breakfast, after the three days of vegetable food, consisted almost entirely of animal food, and then, for at least two hours and a half, the urine was highly alkaline. The increase in the acidity before food on the second day is very marked. It was higher than on any previous occasion. The third day, before dinner, at $5^h\ 55^m$ P.M., the acidity per 1000 grs. urine equaled 16·64 measures. At half-past eight it had increased to 17·46 measures, though in all the previous experiments the acidity diminished after dinner; but at $10^h\ 50^m$ P.M. the urine had become neutral to test-paper. Possibly this increase of acidity was owing to the honey taken at breakfast.

III. On the Influence of Medicines. (*a.*) Sulphuric acid.

For three following days dilute sulphuric acid, specific gravity 1·1077, was taken, in doses of three drachms daily. In all, nine drachms of acid were taken.

Breakfast as in experiments (1.), (2.), (3.), at $8^h\ 45^m$ A.M. Dinner, as before, at $5^h\ 45^m$ P.M. One drachm of dilute acid, in two ounces of distilled water, was taken at $7^h\ 45^m$ A.M. Another at $12^h\ 45^m$ P.M. The last at $4^h\ 50^m$ P.M.

	h	m		Spec. gr.	Acidity per 1000 grs. of urine.	
(11.) Water passed at	7	45	A.M.	1024·8	+20·49 measures.	Thickish from urates.
Water passed at	8	45		1022·5	+13·69	Clear.
Water passed at	10	15		1012·6	+ 8·88	Clear.
Water passed at	11	25		1022·5	− 8·80	Clear.
Water passed at	12	45	P.M.	1026·1	− 3·89	Clear.
Water passed at	3	10		1023·4	+13·68	Clear.
Water passed at	4	50		1024·1	+21·48	Clear.

	h	m		Spec. gr.	Acidity per 1000 grs. of urine.	
Water passed at	5	45	P.M.	1026·2	+24·36 measures.	Clear.
Water passed at	10	0		1030·6	− 7·76	Clear.
Water passed at	3	15	A.M.	1018·1	+ 4·91	Clear.
Water passed at	7	0		1020·1	+14·70	Clear.

(12.) The following day breakfast as before, at $8^h\ 40^m$ A.M. Dinner as before, at $5^h\ 30^m$ P.M. A drachm of dilute sulphuric acid was taken at $8^h\ 10^m$, $12^h\ 45^m$, $4^h\ 30^m$.

Water passed at	8	40		1024·0	+14·64 measures.	Thick from urates.
Water passed at	10	0		1013·4	+ 7·88	Clear.
Water passed at	11	10		1023·3	−13·68	Clear.
Water passed at	12	0		1026·9	− 7·79	Clear.
Water passed at	12	45	P.M.	1026·1	− 3·89	Clear.
Water passed at	3	10		1023·2	+14·66	Clear.
Water passed at	5	30		1024·0	+20·50	Clear.
Water passed at	7	10		1030·4	+24·26	Thick from urates.
Water passed at	10	35		1032·6	+ 6·77	Very thick from urates.
Water passed at	3	35	A.M.	1020·0	+ 5·88	Clear.
Water passed at	6	50		1020·1	+12·74	Clear.
Water passed at	7	45		1022·6	+14·66	Clear.

(13.) The following day breakfast as before, at $8^h\ 40^m$ A.M. Dinner as before, at $5^h\ 40^m$ P.M. Dilute sulphuric acid was taken at 8^h, $1^h\ 25^m$, 5^h.

Water passed at	8	40		1023·4	+17·58 measures.	Clear.
Water passed at	9	50		1018·5	+10·80	Clear.
Water passed at	11	5		1019·9	+ 8·82	Clear.
Water passed at	12	5	P.M.	1025·5	− 4·87	Clear.
Water passed at	12	55		1026·0	+ 3·89	Clear.
Water passed at	2	50		1024·2	+14·64	Clear.
Water passed at	5	40		1023·5	+19·54	Clear.
Water passed at	7	30		1029·1	+12·63	Thick from urates.
Water passed at	10	50		1029·0	+ 2·91	Clear.
Water passed at	5	10	A.M.	1016·1	+ 8·85	Clear.
Water passed at	6	55		1016·5	+11·80	Clear.
Water passed at	8	30		1020·9	+13·71	Clear.

Plate XX. admits of a comparison with those previously given. The nine drachms of dilute sulphuric acid do not appear to heighten the acidity before food, though the diminution of the acidity after food is certainly less marked than when no acid was taken, and mixed diet was eaten. In the third part of this paper, on the Variations of the Sulphates in Health, I shall show that a similar mode of inquiry gave no positive results as to their increase in the urine after sulphuric acid was taken; but by examining all the urine passed in twenty-four hours, positive results were obtained.

A similar course was therefore adopted regarding the acidity of the urine.

These three days' variations confirm those previously given; all show the influence of digestion; the constant decrease of the acidity of the urine after food was taken, and the gradual increase of acidity as the food is absorbed.

The second day, before breakfast, it may be observed that the water made at 7 and at $8^h\ 40^m$ A.M., had very nearly the same degree of acid reaction; that is, during the last hour and forty minutes before breakfast there was no increase in the acidity of the urine. I have previously pointed out that on two occasions there was a diminution of the acidity of the urine just before breakfast.

It may, perhaps, indicate that acid is sometimes separated from the blood by the stomach previous to the food being taken.

A young physician with an irritable stomach, but otherwise in good health, made the following observations on his urine, at my request, for seven days. Breakfast was always immediately after the second testing of the water.

February 20.—$8^h\ 30^m$ A.M. slightly acid. 9 A.M. neutral. 1 P.M. alkaline.

February 21.—$8^h\ 30^m$ A.M. strongly acid. 9 A.M. slightly acid. 12 A.M. alkaline. 4 P.M. slightly acid.

February 22.—7 A.M. slightly acid. $8^h\ 30^m$ and 9 A.M. alkaline. 2 P.M. alkaline. 4 P.M. neutral. $5^h\ 30^m$ P.M. slightly acid.

February 23.—$8^h\ 30^m$ A.M. neutral. 9 A.M. alkaline. $12^h\ 30^m$ P.M. alkaline. $2^h\ 30^m$ P.M. slightly acid.

February 24.—$8^h\ 30^m$ A.M. slightly acid. 9 A.M. alkaline. $11^h\ 30^m$ A.M. alkaline.

February 25.—$8^h\ 30^m$ A.M. slightly acid. 9 A.M. neutral. 2 P.M. alkaline. 4 P.M. slightly acid.

February 26.—$8^h\ 30^m$ A.M. strongly acid. 9 A.M. slightly acid. $9^h\ 30^m$ A.M. alkaline.

Thus, just before breakfast, the urine was neutral twice, and alkaline thrice, in seven experiments.

In the previous experiments, after honey had been taken for breakfast, the acidity was seen not to diminish immediately after dinner; and the same thing happened the second day after sulphuric acid was taken; at $5^h\ 30^m$ P.M., immediately before dinner, the acidity was 20·50 measures; nearly two hours afterwards, at $7^h\ 10^m$ P.M., the acidity had increased to 24·26. At $10^h\ 30^m$ P.M. it had diminished to 6·77. The third day, with the same quantity of sulphuric acid, no increase in the acidity, two hours after food, was observed.

As no positive proof was obtained of the influence of sulphuric acid on the acidity of the urine by examining the water passed at different hours, I next endeavoured to determine whether this acid produced any effect on the total amount of acidity of the urine in twenty-four hours.

It was necessary for the purpose of comparison, that the total acidity of the urine in twenty-four hours, when sulphuric acid was not taken, should be first known. The breakfast and dinner were of meat and bread, coffee, wine and water; the same for the six days.

	A.M. h m	A.M. h m	oz.	Spec. gr.	Total carb. of soda required.
(14.) Total quantity from	7 30	to 7 30	=46¼	1022·4	=14·99 grains
					={about 8·80 measures of acid. per 1000 grs. of urine.
(15.) Total quantity from	7 30	to 7 30	=35¾	1027·1	=16·87 grains
					=about 12·65 acid. per 1000 urine.
(16.) Total quantity from	7 30	to 7 30	=44	1023·8	=14·31 grains
					=about 8·78 acid. per 1000 urine.

During each of the three following days, three drachms of dilute sulphuric acid, specific gravity 1·1077, were taken, in three and a half ounces of distilled water; the greater part from 9 to 12 A.M.

	A.M. h m	A.M. h m	oz.	Spec. gr.	Total carb. of soda required.
(17.) Total quantity from	7 30	to 7 30	=40	1026·2	=17·59 grains
					={about 11·88 measures of acid. per 1000 grs. of urine.
(18.) Total quantity from	7 30	to 7 30	=54	1020·3	=17·64 grains
					=about 8·82 acid. per 1000 urine.
(19.) Thick from urates . . .			=40	1028·6	=25·92 grains
					=about 17·50 acid. per 1000 urine.

From the comparison of the total amount of carbonate of soda required to neutralize the acidity of the urine, there is no doubt that sulphuric acid does slightly increase the acidity of the urine. The following day no examination was made.

	A.M. h m	A.M. h m	oz.	Spec. gr.	Total carb. of soda required.
Total quantity from	7 30	to 7 30 the next day	=45	1026·7	=4·82 grains
					={about 3·89 measures of acid. per 1000 grs. of urine.

The conclusions from these experiments are,—

I. As regards the variations of the acidity of the urine for three days on mixed diet. The acidity soon after food was found to decrease, and to attain its lowest limit from three to five hours after breakfast and dinner; sooner, however, after breakfast than after dinner. The acidity then gradually increased, and attained its highest limit just before food. Once previous to breakfast, the urine was found more acid an hour before breakfast than it was immediately before food.

If no food was taken the acidity of the urine did not decrease, but remained nearly the same for twelve hours. It fell immediately after food was taken.

II. As to the influence of animal and vegetable food.

When animal food only was taken, the diminution of the acidity after food was more marked and more lasting, than when a mixed diet was taken; and the acidity before food rose rather higher with a mixed diet than it did with animal food.

When vegetable food only was taken the contrast with animal food was very marked. The urine did not decrease in acidity to the same degree; though it became neutral, it did not become highly alkaline. The increase in the acidity of the urine was by no means so marked as the decrease of the alkalescence. The acidity of the urine was rather higher with the vegetable food than it was with animal food.

III. As to the effect of dilute sulphuric acid.

Dilute sulphuric acid, taken in large doses, did not produce any very decided results. Nine drachms of dilute acid in three days slightly diminished the decrease in the acidity of the urine after food. The acidity before food was very slightly, if at all, increased thereby.

When the acidity of the whole quantity of water passed in twenty-four hours, for three days when no sulphuric acid was taken, is compared with the acidity when nine drachms of dilute sulphuric acid were taken, the increase is sufficiently distinct to prove that the acid does pass off in the urine.

The result of these experiments is, that the acidity of the urine is always changing, and that the changes depend on the state of the stomach.

When much acid is in the stomach, the acidity is then diminished. As the acid returns from the stomach, the acidity of the urine increases, and usually reaches its highest limit before food is again taken.

Animal food causes a greater oscillation in the acidity of the urine than vegetable food does; and when no food is taken the oscillation is very small.

The diurnal variations in the acidity of the urine make it highly probable that corresponding variations occur in the alkalescence of the blood; such diurnal variations being produced by the quantity of acid poured into the stomach for the purpose of dissolving the food.

When the food is irritating, or the stomach in an irritable state, much acid is poured out, and the effects on the blood and urine are more marked than they are when less acid is secreted.

Dr. Prout's capital experiment of hydrochloric acid in the stomach during digestion, gives the key to these diurnal variations of the acidity of the urine, and may lead to the discovery of the diurnal variations of the alkalescence of the blood.

Part II.—*On the Simultaneous Variations of the amount of Uric Acid and the Acidity of the Urine in a Healthy State.*

The variations which occur in the acidity of the urine are of themselves of very great interest, whether in relation to health or to disease; whilst the determination of the amount of uric acid and acidity at the same time directly solves the question, whether the acidity of the urine depends on the uric acid; and thus alone can clear views of the causes of the precipitation of the urate of ammonia in the urine be obtained. Moreover, it is necessary to trace fully the variations of the uric acid in health before deductions can safely be made regarding the variations of the amount of uric acid in different diseases.

The following course was taken. A healthy man who took food twice daily, and moderate exercise for three hours, was the subject of the experiments. A bottle containing 1000 grains of water was filled with urine, at a temperature of 60°. It was weighed, and the fluid was heated to 120°, when a test alkaline solution was dropped from a graduated tube, and well-stirred, until the urine became just neutral to very delicate test-paper.

The test solution was prepared by taking dry and pure carbonate of soda, and dissolving it in so much water that every measure of a graduated tube contained $\frac{1}{13}$th of a grain of carbonate of soda in solution.

To determine the amount of uric acid, upwards of 2000 grains of urine were mixed with strong hydrochloric acid, in the proportion of a drachm to the ounce, and left to stand for at least twenty-four hours. The fluid was poured off, and the residue thrown on a weighed filter, slightly washed, and dried *in vacuo* over sulphuric acid.

(1.) Breakfast on bread, coffee, and two eggs, at 9 A.M. Dinner at $7\frac{1}{2}$ P.M. Fish meat, and vegetables, with water.

	Spec. gr.	Acidity per 1000 grs. of urine. measures.	Uric acid per 1000 grs. of urine. grain.
Water passed at 2 P.M. clear.	1023·1	9·77	0·39
Water passed at 7 clear.	1026·3	27·28	0·048
Water passed at 11 cloudy.	1030·0	26·21	0·584
(2.) The following day, breakfast as yesterday. Dinner at $6\frac{1}{2}$ P.M.			
Water passed at 2 slightest cloud.	1025·4	4·88	0·731
Water passed at $6\frac{1}{2}$ clear.	1026·7	23·37	0·14
Water passed at 11 clear.	1025·1	7·80	0·61
(3.) Following day, breakfast as before. Dinner at $6\frac{1}{4}$ P.M.			
Water passed at 1 clear.	1025·5	9·75	0·53
Water passed at $6\frac{1}{4}$ clear.	1023·1	22·48	0·17
Water passed at 11 clear.	1031·1	11·64	0·92
(4.) As yesterday. Dinner at $\frac{1}{4}$ to 6 P.M.			
Water passed at $1\frac{1}{4}$ very thick.	1027·8	23·35	0·53
Water passed at $5\frac{3}{4}$ clear.	1027·7	27·24	0·12
Water passed at $10\frac{1}{2}$ clear.	1021·0	13·71	0·39
(5.) As yesterday. Dinner at 7 P.M.			
Water passed at $2\frac{1}{2}$ clear.	1023·1	17·59	0·44
Water passed at 7 clear.	1024·9	30·24	0·146
Water passed at 11 clear.	1026·5	9·74	0·634
Average mean of five days.			
Between 1 and 2 P.M.	1025·0	13·07	0·52
Between 6 and 7 P.M.	1025·7	26·12	0·12
Between 10 and 11 P.M.	1026·7	13·81	0·62

From these experiments it appears that the uric acid is increased three, four, or five times in quantity by food; whilst the acidity is lessened to one-half what it was before food. The quantity of uric acid varies before food from 0·048 gr. per 1000 grs. of urine, specific gravity 1026·3, to 0·17 gr. per 1000 grs. of urine, specific gravity 1023·1. After food the quantity of uric acid varies from 0·39 gr. per 1000 grs. of urine, specific gravity 1021·0, to 0·92 gr. per 1000 grs. of urine, specific gravity 1031·1. The acidity before food varies from 23·37 grs. per 1000 grs. of urine, specific gravity 1026·7, to 30·24 per 1000 urine, specific gravity 1024·9. After food the acidity varies from 7·80 per 1000 urine, specific gravity 1025·1, to 26·21 per 1000 urine, specific gravity 1030·0.

The uric acid was lowest when 0·048 gr. per 1000 grs. of urine, specific gravity 1026·3, was present, then the acidity was 27·28 measures. The uric acid was highest when there was 0·92 gr. per 1000 grs. of urine, specific gravity 1031·1; the acidity then was 11·64 measures only.

(6.) A child twenty-three months old, fed at 1 P.M. on bread with some meat and milk, gave—

	Spec. gr.	Acidity per 1000 grs. of urine. measures.	Uric acid per 1000 grs. of urine. grain.
Water passed at 1 P.M.	1013·6	8·88	0·27
Water passed at 5 P.M.	1022·0	14·67	0·65

Both specimens deposited uric acid crystals on standing; the first in twenty-four hours, the last in six hours.

II. I next endeavoured to ascertain what was the influence of different kinds of food on the variations of the uric acid and acidity.

For three successive days vegetable food alone was taken, with water and coffee. Breakfast at 9¼ A.M. Dinner at 6¼ P.M.

	Spec. gr.	Acidity per 1000 grs. of urine. measures.	Uric acid per 1000 grs. of urine. grain.
(7.) Water passed at 1¼ P.M. A few uric acid crystals formed on long standing	1022·9	17·60	0·19
Water passed at 6¼ P.M. clear .	1025·4	21·45	0·17
Water passed at 10¼ P.M. clear .	1014·8	12·81	0·19
(8.) Breakfast and dinner as yesterday. Water at 10½ A.M. thrown away, clear.			
Water passed at 2½ P.M. clear .	1021·65	8·89	0·565
Water passed at 6¼ P.M. clear .	1024·0	26·36	0·049
Water passed at 10½ P.M. clear .	1026·2	3·29	0·636
Water passed at 6½ A.M. clear .	1024·2	19·52	0·665
(9.) Breakfast and dinner the same as yesterday. Water at 9 thrown away.			
Water passed at 10½ A.M. thick on standing from urates . . .	1025·6	12·67	1·01

	Spec. gr.	Acidity per 1000 grs. of urine. measures.	Uric acid per 1000 grs. of urine. grain.
Water passed at 2½ P.M. cloudy from phosphates	1024·5	alkaline	0·61
Water passed at 6½ P.M. clear .	1025·9	26·31	0·34
Water passed at 10½ P.M. clear .	1014·8	alkaline	0·14
Water passed at 6½ A.M. clear .	1014 8	7·88	0·049

When vegetable food only is taken the same variations are seen as when mixed diet is eaten. The acidity is most before food. The highest acidity was 26·36 measures; then the uric acid =0·049 gr. per 1000 grs. of urine, specific gravity 1024·0. The uric acid was most after food; the highest amount being 1·01 gr. per 1000 grs. of urine, specific gravity 1025·6. The acidity then was only 12·67 measures per 1000 grs. of urine. The variations of the acidity in (9.) are very remarkable.

For three days in succession animal food only was taken, meat, eggs, cheese, coffee and water. Breakfast at 9 A.M. Dinner at a quarter to 6 P.M.

	Spec. gr.	Acidity per 1000 grs. of urine. measures.	Uric acid per 1000 grs. of urine. grain.
(10.) Water passed at 9 A.M. clear, uric acid crystals in four hours .	1023·3	30·41	0·69
Water passed at 11 A.M. clear .	1015·2	alkaline	0·24
Water passed at 1 P.M. thick from phosphates	1022·2	alkaline	0·68
Water passed at ¼ to 6 P.M. clear	1023·9	20·50	0·34
Water passed at 10½ P.M. clear	1024·1	11·71	0·63
(11.) Breakfast at 9 A.M. Dinner at half-past 6 P.M.		Food as before.	
Water passed at 2½ P.M. clear	1022·7	7·82	0·44
Water passed at 6½ P.M. clear	1024·8	21·46	0·049
Water passed at 11½ clear	1029·9	16·50	0·77
(12.) Breakfast at 9 A.M. Dinner at half-past 6 P.M.		Animal food only.	Water at 9 A.M. thick, and was thrown away.
Water passed at 2½ P.M. thick	1024·7	16·59	0·756
Water passed at 6½ P.M. clear	1027·1	24·34	0·073
Water passed at ¼ to 11 P.M. thick	1027·8	18·48	1·022
Water passed at 4½ A.M. clear	1021·4	16·64	0·318

In these experiments also the uric acid is increased after food, and the acidity is diminished. The highest amount of uric acid was 1·022 gr. per 1000 grs. of urine, specific gravity 1027·8. The acidity at the same time was 18·48 measures. Previous to food the same day the uric acid =0·073 gr. per 1000 grs. of urine, specific gravity 1027·1; then the acidity =24·34 measures.

Comparing the three days on animal food with the three days on vegetable food, we have the highest amount of uric acid on the third day; in the one case =1·022 gr.,

specific gravity 1027·8, and in the other 1·01 gr. per 1000 grs. of urine, specific gravity 1025·6, after dinner in the one case and after breakfast in the other. The lowest amount in both was 0·049 gr. per 1000 urine, specific gravity 1024·8; and 0·049 gr., specific gravity 1024·0, in both instances before dinner. So that neither as regards the diminution nor the increase of the amount of uric acid can any positive result be obtained from these experiments on the influence of animal and vegetable food.

The variations in the acidity are not very different on animal or on vegetable food; the acidity rises higher when vegetable food is taken than when animal food only was taken.

I next endeavoured, if possible, to determine the effect of exercise. No food was taken from dinner on the previous day to dinner this day at a quarter to six; both meals consisted of mixed diet of bread, meat and potatoes. The exercise was moderate between three and six.

No water was passed from 11 the previous night to 6 A.M.

	Spec. gr.	Acidity per 1000 grs. of urine. measures.	Uric acid per 1000 grs. of urine. grain.
(13.) Water passed at 6 A.M. clear .	1026·7	13·63	0·63
Water passed at 11 A.M. clear .	1024·3	19·52	0·63
Water passed at ½ to 6 P.M. . .	1027·9	12·65	0·73
Water passed at 11 P.M. clear .	1021·0	alkaline	0·49
Water passed at 6 A.M. clear .	1022·3	22·49	0·58

(14.) Nothing was taken from dinner on the previous day until 5½ P.M. this day. Strong exercise was taken from 2½ to 5½ P.M. Pulse always above 100. At nine urine clear and thrown away.

	Spec. gr.	Acidity per 1000 grs. of urine. measures.	Uric acid per 1000 grs. of urine. grain.
Water passed at 1 P.M, few uric acid crystals	1022·5	19·56	0·344
Water passed at 5½ P.M. clear	1025·2	25·36	0·268
Water passed at 10½ P.M. very thick, some uric acid crystals.	1030·0	19·41	1·286
Water passed at 1½ A.M. very thick, some uric acid crystals	1027·1	17·52	0·924
Water passed at 7 A.M. very thick, some crystals of uric acid	1025·5	33·14	0·878

(15.) Nothing was taken from dinner on the previous day until ten minutes after five this day. Moderate exercise was taken from 2 to 5 P.M.

	Spec. gr.	Acidity per 1000 grs. of urine. measures.	Uric acid per 1000 grs. of urine. grain.
Water passed at 6 10 A.M. clear . .	1025·7	15·59	0·098
Water passed at 11 20 A.M. thick .	1024·8	13·96	0·61
Water passed at 5 10 P.M. thick . .	1028·3	14·90	0·52
Water passed at 11 P.M. clear . .	1031·1	2·85	0·87
Water passed at 5 40 A.M. clear . .	1026·9	10·71	0·12

Hence no conclusion can be drawn regarding the effect of exercise on the excretion of uric acid. The influence of food lasts so long in increasing the amount of urates that no results regarding exercise could be obtained; experiment (14) is no positive proof of the increase or diminution of the uric acid by exercise.

The three following days the total amount of uric acid excreted in twenty-four hours was determined. The breakfast and dinner were of meat and bread, coffee, wine and water: the same each day.

	Uric acid. gr.	Spec. gr.	Quantity of urine.	Uric acid per 1000 grs. of urine.
(16.) Total quantity from $7^h\ 30^m$ A.M. to $7^h\ 30^m$ A.M.	=5·9	1022·4	=46$\frac{1}{3}$	0·29 gr.
(17.) The following day. Total quantity . .	=7·7	1027·1	=35$\frac{2}{3}$	0·48
(18.) The following day. Total quantity . .	=7·0	1023·8	=44$\frac{2}{3}$	0·36

In the course of the following three days nine drachms of dilute sulphuric acid were taken. The food was the same as before.

	Uric acid. gr.	Spec. gr.	Quantity of urine.	Uric acid per 1000 grs. of urine.
(19.) Total quantity from $7^h\ 30^m$ A.M. to 7^h A.M. . .	=7·3	1026·2	=40$\frac{2}{3}$	0·41 gr.
(20.) The following day, total quantity	=6·5	1020·3	=54$\frac{2}{3}$	0·27
(21.) Thick from urates, the following day, quantity	=9·9	1028·6	=40$\frac{2}{3}$	0·56

The conclusions from these experiments are,—

I. As regards the variations of the acidity and uric acid when mixed diet was taken.

	Per 1000 grs. of urine.	Spec. gr.
The uric acid varies before food from . . .	0·048 gr.	1026·3
The uric acid varies before food to	0·17 gr.	1023·1
It varies after food from	0·39 gr.	1021·0
It varies after food to	0·92 gr.	1031·1
The acidity varies before food from	23·37 measures	1026·7
The acidity varies before food to	30·24 measures	1024·9
It varies after food from	7·80 measures	1025·1
It varies after food to	26·21 measures	1030·0

II. As to the influence of vegetable and animal food and exercise.

When vegetable food only was taken the uric acid was highest after food,

	Per 1000 grs. of urine.	Spec. gr.
Being at most	1·01 gr.	1025·6
Then the acidity was	12·67 measures	
The uric acid was least before food, being at least	0·049 gr.	1024·0
Then the acidity was	26·36 measures	

When animal food only was taken the uric acid was highest after food,

Being at most	1·022 gr.	1027·8
Then the acidity was	18·48 measures	
The lowest uric acid was before food, being at least	0·049 gr.	1024·8
Then the acidity was	21·46 measures.	

There is no great difference between animal and vegetable food; and no proof was obtained of the influence of exercise on the excretion of uric acid.

From the experiments on the total amount of uric acid excreted in twenty-four hours, it appears as though the deficiency one day was followed by an excess the following day.

The result of these experiments is, that there is no relation between the acidity of the urine and the amount of uric acid in it. The urine that was most acid contained least uric acid. That which contained most uric acid was not highly acid.

All food causes an increase in the amount of uric acid in the urine, and there is no decided difference between vegetable and animal food, either as to the increase or diminution of the amount of uric acid in the urine.

These experiments also show the variations of the acidity of the urine which the food produces. They were made four months previous to the experiments in the first part of this paper, which were made in October. Those here given were made in June.

On the Deposit of Urates in the Urine.

That the amount of urates in the urine is not the only cause of their deposit, the following experiments are sufficient to prove:—

	h	m		Spec. gr.		Acidity and uric acid per 1000 grs. of urine. grain.	
Water passed at	5	5	P.M.	1024·9	18·53 measures	0·22	No deposit.
Water passed at	7	35		1029·2	15·54	0·29	Thickish from urates.
Water passed at	10	5		1027·2	alkaline	0·33	No deposit.
Another day at	5	50	P.M.	1024·4	21·47	0·07	No deposit.
	7	55		1029·6	15·57	0·31	Thickish from urates.
	10	45		1029·8	alkaline	0·90	No deposit.
Another day at	10		P.M.	1030·6	alkaline	0·76	No deposit.
The same is well seen in (15.).							
at	5	10	P.M.	1028·3	14·90	0·52	Thick from urates.
	11			1031·1	2·85	0·87	Clear.

The influence of temperature is always shown in the precipitation of urates taking place on the cooling of the urine. The low temperature of the night frequently will cause a deposit which would not form during the day.

The influence of the acidity of the urine on the deposit can always be shown by adding any acid to the urine passed soon after food. Two portions being taken, and the one being made more acid than the other, will show a difference in the time or degree of deposit.

The influence of water in preventing a deposit is shown, by adding distilled water to urine which would give a precipitate. Evaporation under the air-pump takes away

water, increases the proportion of urate of ammonia to the water, at the same time it increases the acid reaction of the urine. By carrying the evaporation far enough, deposit of urate of ammonia always occurs.

The influence of strong light is seen in its occasionally causing a deposit only on the side of the glass nearest to the light. Brisk agitation also sometimes will hasten or cause a deposit of urate of ammonia.

From the above experiments and observations, it follows that the deposit of urate of ammonia does not generally depend only on the proportion of the water to the urate of ammonia being relatively or positively diminished. Nor does it depend solely on the degree of acidity of the urine; but it results from the simultaneous action of both causes, aided always by a low temperature.

Alkaline urine will hold in solution a great excess of urate of ammonia, and very feebly acid urine will dissolve much more urate of ammonia than very highly acid urine. But highly acid urine will give no precipitate of urate of ammonia if only a very small quantity of that substance is present in it.

The deposit of urate of ammonia is therefore the result of the united action of three causes:—

1. Decrease of temperature.
2. Increased proportion of urate of ammonia to the water, positively or relatively.
3. Increased acidity of the urine.

Sometimes one cause, sometimes the other, is the most efficient; but they are all usually concerned in causing the deposit of urate of ammonia.

PART III.—*Variations of the Sulphates in the Urine in the healthy state, and on the influence of Sulphuric Acid, Sulphur and the Sulphates, on the amount of the Sulphates in the Urine.*

Before tracing the variations of the sulphates in disease, it is necessary to determine their limits in the healthy state; and it is also desirable to know as far as possible what the effect of medicinal substances on their amount may be. Thus the influence of sulphuric acid, of the sulphates, and of sulphur on the amount of sulphuric acid excreted, must be determined before the results of diseased action can be estimated. By this means alone can it be shown what is the effect of ordinary causes or remedies, and what is the effect of disease.

A healthy man taking food twice daily, with moderate exercise for three hours, was the subject of the following experiments. The specific gravity of the urine was first taken. To a weighed quantity, usually about 500 grains, chloride of barium in excess was added, and then a few drops of nitric acid. Heat was then applied until the liquid boiled briskly, when the sulphate of baryta was filtered, well-washed, and ignited in a platinum crucible, after which it was weighed.

By this method very accurate results could be obtained.

(1.) Breakfast on bread and cocoa at 8½ A.M. Dinner on meat, potatoes, bread and water at 6½ P.M.

	Spec. gr.	Sulphate of baryta per 1000 grs. of urine. grains.
Water passed at 3 P.M. filtered	1028·2	9·16
Water passed at 6½ clear	1027·0	8·41
Water passed at 10½ filtered	1033·9	15·23

(2.) Food as before. Between 3 and 7 P.M. strong exercise was taken. Dinner at 7 P.M.

Water passed at 7 P.M. clear	1025·3	7·07
Water passed at 11 filtered	1030·8	11·53
Water passed at 1 A.M. clear	1025·1	6·47

(3.) Breakfast at 9 A.M. as before. Dinner at 6½ P.M.

Water passed at 3½ P.M. filtered	1026·8	7·96
Water passed at 6½ clear	1027·0	7·36
Water passed at 10½	1031·0	10·63

(4.) Breakfast at 9 A.M. as before. Water passed at 10 A.M. thrown away. Dinner 6¼ P.M.

Water passed at 12½ P.M. filtered	1025·6	7·52
Water passed at 3½	1025·9	7·95
Water passed at 6¼	1026·0	8.25
Water passed at 10½ clear	1029·3	9·45

(5.) Breakfast at 9 A.M. as before. Dinner at 5½ P.M.

Water passed at 1 P.M. clear	1024·0	6·48
Water passed at 3¼	1023·6	6·03
Water passed at 5½	1027·6	8·56
Water passed at 9½ filtered	1030·8	12·43
Average mean of five days after dinner, with perfect rest	1031·1	11·85
Average mean of five days just before dinner, after exercise	1026·5	7·93
Average of four days, longer before dinner	1026·1	7·77

From these experiments it appears that the sulphuric acid is much increased in the water passed after food, the quantity varying—

From 15·23 grs. of sulphate of baryta per 1000 grs. of urine, specific gravity 1033·9
To 9·49 grs. of sulphate of baryta per 1000 grs. of urine, specific gravity 1029·3
The mean of all the experiments after food being 11·85 per 1000 urine, specific gravity 1031·1.

The quantity of sulphuric acid is much less in the water secreted a long time after food, varying—

From 8·56 grs. of sulphate of baryta per 1000 grs. of urine, specific gravity 1027·6
To 7·07 grs. of sulphate of baryta per 1000 grs. of urine, specific gravity 1025·3
The mean of all the experiments before food being 7·93 grs. per 1000 grs. of urine, specific gravity 1026·5.

(6.) A child two years old, fed on bread with some meat and milk, gave in the water passed during the night, acid, specific gravity =1014·6, sulphate of baryta 4·66 grs. per 1000 grs. of urine.

(7.) On the same food another night, specific gravity =1013·5, sulphate of baryta 3·88 grs. per 1000 grs. of urine.

II. I next endeavoured to ascertain by what causes the variations were produced. And first (*a.*) with regard to food of different kinds. For three consecutive days bread alone, with a little rice and water and tea, was taken at the same hours as food had been taken in the previous experiments.

		Spec. gr.	Sulphate of baryta.
(8.) Water passed at 6 P.M.	clear	1019·46	5·31 grs. per 1000 grs. of urine.
Water passed at 11	filtered	1025·30	10·57
(9.) Breakfast and dinner as on the previous day. Distilled water only was taken.			
Water passed at 3 P.M.	filtered	1025·88	8·03 grs. per 1000 grs. of urine.
Water passed at 6 . .		1026·00	7·31
Water passed at 11 . .		1030·40	13·21
(10.) Breakfast and dinner as on the previous day. Spring water drunk.			
Water passed at 3 P.M. . .		1027·56	9·53 grs. per 1000 grs. of urine.
Water passed at 6 . .		1028·58	9·46 per 1000 urine.
Water passed at 11 . . .		1031·86	13·68
(11.) Animal food only was taken for three days with tea and water. Breakfast at 9 A.M.: animal food and tea. Dinner at 6 P.M.: animal food and water. 1 P.M. water was thrown away.			
Water passed at 6 P.M.	clear	1023·02	6·86 grs. per 1000 grs. of urine.
Water passed at 11 . . .		1021·10	7·69
(12.) Breakfast and dinner as on the previous day. Distilled water only taken.			
Water passed at 3 P.M. . .		1021·30	6·30 grs. per 1000 grs. of urine.
Water passed at 6 . . .		1025·52	9·12
Water passed at 11 . . .		1023·60	10·19
(13.) Breakfast and dinner as on the previous day. Common water taken.			
Water passed at 3 P.M.	filtered	1023·92	8·36 grs. per 1000 grs. of urine.
Water passed at 6	clear	1025·44	9·30
Water passed at 11	filtered	1026·24	11·14

From the comparison of these numbers with the average previously given, no deduction can be drawn as to the peculiar influence of animal or vegetable food on the amount of the sulphates in the urine. After either animal or vegetable food the sulphates are increased.

II. (*b.*) I then tried to determine the effect of exercise.

(14.) Nothing whatever was taken from dinner the preceding day, which consisted of meat only, until dinner this day, which consisted of bread, tea, and an egg. The

water made at a quarter to 2 P.M. was thrown away. From four to a quarter past 6 moderate and sometimes strong exercise was taken.

	Spec. gr.	Sulphate of baryta.
Water passed at 4 P.M. filtered .	1029·52	8·76 grs. per 1000 grs. of urine.
Water passed at $6\frac{1}{4}$ . . .	1031·18	11·26 11·23
Water passed at $10\frac{1}{4}$ . . .	1029·04	12·34

(15.) Nothing whatever was taken from dinner the preceding day, which consisted of bread and meat, until dinner this day. Water made at 1 P.M. thrown away. From 3 to 6, at times, gentle exercise was taken.

	Spec. gr.	Sulphate of baryta.
Water passed at 3 P.M. filtered .	1024·78	5·48 grs. per 1000 grs. of urine.
Water passed at 6	1026·88	7·03
Water passed at 11	1027·50	9·34

(16.) Nothing was taken from dinner the preceding day to dinner this day. The water passed at 1 P.M. was thrown away. From 3 to 6 strong exercise was taken.

	Spec. gr.	Sulphate of baryta.
Water passed at 3 P.M. filtered .	1021·20	3·27 grs. per 1000 grs. of urine.
Water passed at 6	1019·10	3·55 3·47
Water passed at $10\frac{1}{2}$ clear . .	1027·00	8·00

From these numbers it appears that food has more influence on the sulphates than exercise has. (14.) shows that exercise has a decided effect in increasing the sulphates. The increase is less marked in (15.); the same is seen in (16.) to a much less degree in consequence of the diminution of the specific gravity.

III. The influence of different medicinal substances admits of a clearer demonstration.

(*a.*) (17.) Breakfast as before at 9 A.M. Dinner at $6\frac{1}{2}$ P.M. At 1 P.M. thirteen drops of sulphuric acid, specific gravity = 1786·4, equivalent to above $1\frac{1}{4}3$ of dilute sulphuric acid, were taken in water.

	Spec. gr.	Sulphate of baryta.
Water passed at 1 P.M. clear . .	1027·6	7·51 grs. per 1000 grs. of urine.
Water passed at 3 . . .	1028·7	9·75
Water passed at $6\frac{1}{2}$ . . .	1027·9	10·36
Water passed at 10 . . .	1031·5	12·15

(18.) Breakfast as before. Dinner at 6 P.M. At 1 P.M. rather less sulphuric acid was taken.

	Spec. gr.	Sulphate of baryta.
Water passed at $12\frac{1}{2}$ P.M. . . .	1022·5	4·07 grs. per 1000 grs. of urine.
Water passed at 3	1022·2	5·28
Water passed at 6	1021·9	6·19
Water passed at $10\frac{1}{2}$	1028·1	10·66

(19.) Breakfast as before. Dinner at 6 P.M. At 1 P.M. thirteen drops of sulphuric acid as before.

	Spec. gr.	Sulphate of baryta.
Water passed at 1 P.M. . . .	1018·8	3·48 grs. per 1000 grs. of urine.
Water passed at ¼ to 3 . . .	1012·6	2·13
Water passed at 6	1017·7	4·09
Water passed at 10	1026·2	11·43

(20.) Breakfast as before. Dinner at 6 P.M. At 1 P.M. twenty drops of sulphuric acid taken as before.

Water passed at 1 P.M. . . .	1022·8	4·83 grs. per 1000 grs. of urine.
Water passed at 3	1019·9	4·99
Water passed at 6	1022·2	6·79
Water passed at 10½	1021·3	9·52

(21.) Breakfast as before. Dinner as before. No sulphuric acid taken.

Water passed at 3 P.M. . . .	1025·0	7·08 grs. per 1000 grs. of urine.
Water passed at 6	1023·9	5·88
Water passed at 10½	1029·4	10·79

From experiment (17.) it seemed that the sulphates were slightly increased by the sulphuric acid which was taken. The other experiments hardly confirm this deduction, and on this account I tried whether a course of sulphuric acid would give more marked results.

(22.) After four days in which dilute sulphuric acid, specific gravity 1115·3, was taken; three drachms the first day and two drachms the three following days. Breakfast and dinner the day after the course of sulphuric acid were the same as in the previous experiments.

		Spec. gr.	Sulphate of baryta.
Water passed at 1 P.M.	clear . .	1027·4	7·51 grs. per 1000 grs. of urine.
Water passed at 3	filtered .	1025·4	8·73
Water passed at 6	clear . .	1026·5	8·72
Water passed at 10¼	filtered .	1030·2	11·99

(23.) No sulphuric acid was taken on the day of experiment (22.). For the next three days three drachms of dilute sulphuric acid were taken the first day, two drachms the second, and three drachms the third day.

The following day (seventeen drachms of dilute sulphuric acid having been taken in the eight previous days) the breakfast and dinner were as before.

		Spec. gr.	Sulphate of baryta.
Water passed at 1 P.M.	filtered .	1026·0	7·37 grs. per 1000 grs. of urine.
Water passed at 3	. . . .	1025·9	7·22
Water passed at 6½	clear . .	1023·3	5·43
Water passed at 10	filtered .	1028·1	10·66

From these experiments it does not appear at all certain that dilute sulphuric acid does pass off in the urine. The question being still undecided, the amount of sulphates in the whole quantity of water passed in twenty-four hours, for three successive days, when no sulphuric acid had been taken, was compared with the amount of sulphates in the whole quantity of water passed in twenty-four hours, for the three succeeding days, when sulphuric acid had been taken. The breakfast and dinner were the same for the six days.

	Spec. gr.	Sulphate of baryta.
(24.) Total quantity of water passed in twenty-four hours, from 7 A.M. to 7 A.M. = 37½ ounces, filtered	1024·2	7·75 grs. per 1000 grs. of urine. 7·66
(25.) The following day = 42 ounces, clear	1023·4	9·18 9·20
(26.) The following day = 34 ounces, filtered	1026·1	7·83

During each of the three following days half an ounce of dilute sulphuric acid, specific gravity = 1108·4, was taken in distilled water, the greater part from 9 to 12 A.M.

	Spec. gr.	Sulphate of baryta.
(27.) Total quantity 46 ounces, filtered	1024·2	9·56 grs. per 1000 grs. of urine. 9·64
(28.) The following day 42½ ounces, clear	1024·0	11·66 11·64
(29.) The following day 43 ounces, clear	1025·4	13·10 12·81

By comparing these experiments, it is certain that dilute sulphuric acid, taken in very large quantity, does cause an increase in the amount of sulphates passing off in the urine.

III. (*b.*) (30.) Breakfast at 9 A.M. Dinner at 6 P.M.: the water made at 11 A.M. was thrown away, and 61½ grains of dry sulphur in fine powder were taken.

	Spec. gr.	Sulphate of baryta.
Water passed at 1 P.M. filtered .	1020·2	5·44 grs. per 1000 grs. of urine.
Water passed at 6	1023·1	7·99
Water passed at 11	1027·6	13·37
(31.) Experiment repeated.		
Water passed at 1 P.M. clear . .	1012·2	2·89
Water passed at 6	1020·7	6·20
Water passed at 11 filtered .	1026·2	11·76
(32.) Experiment repeated.		
Water passed at 1 P.M. clear . .	1014·6	4·19
Water passed at 6	1022·5	10·26
Water passed at 11 filtered . .	1025·4	15·05

(33.) Experiment repeated.

	Spec. gr.	Sulphate of baryta.
Water passed at 1 P.M. clear	1018·9	6·81 grs. per 1000 grs. of urine.
Water passed at 3 .	1018·0	6·52
Water passed at 6 .	1025·6	11·89
Water passed at 11 filtered	1027·9	14·74

(34.) Experiment repeated.

Water passed at 1 P.M. filtered	1023·0	7·99
Water passed at 3 clear . .	lost	
Water passed at 6 clear .	1020·7	7·11
Water passed at 11 filtered .	1028·8	15·15

61½ grains of dry sulphur taken each day.

Average of five days after dinner and rest	1027·1	14·01 grs. per 1000 grs. of urine.
Immediately before dinner after exercise	1022·5	8·69

Comparing this average of experiments 30, 31, 32, 33, 34, with the average of experiments 1, 2, 3, 4, 5, it is seen that the sulphates are positively increased in the urine when sulphur is taken into the stomach.

III. (*c.*) (35.) Breakfast 9 A.M. Dinner at 6½ P.M.: at 1 P.M. 123½ grains of dry sulphate of potash were taken in 1½ ounce of distilled water. It did not act on the bowels.

	Spec. gr.	Sulphate of baryta.
Water passed at 1 P.M. clear	1017·7	3·03 grs. per 1000 grs. of urine.
Water passed at 3 . . .	1016·7	3·00
Water passed at 6½ . . .	1020·8	6·65
Water passed at 10½ . . .	1026·0	12·18

(36.) The same quantity of sulphate of potash taken at 11 A.M.

Water passed at 1 P.M. clear	1020·2	3·17
Water passed at 3½ . .	1024·0	8·74
Water passed at 6½ . .	1024·2	12·51
Water passed at 10½ . .	1032·4	20·49

(37.) Experiment repeated.

Water passed at 1 P.M. clear	1021·6	3·17
Water passed at 3 . .	1021·4	4·98
Water passed at 6 . .	1024·0	9·04
Water passed at 10½ filtered	1030·8	15·72

Hence 123 grains of sulphate of potash began to increase the amount of sulphates in the urine from four to six hours after they were taken; and the effect was strongly marked from seven to twelve hours afterwards.

In my next paper, on the sulphates in the urine in disease, many instances will be

given of an increase in the amount of sulphates in consequence of sulphate of magnesia having been taken in doses of about 2 drachms. The highest instances were—

	Spec. gr.	Sulphate of baryta.
In one case urine . .	1028·0	contained 15·89 grs. per 1000 grs. of urine.
In another case urine .	1024·3	contained 22·55 grs.

The conclusions from these experiments are,—

I. That the sulphate of baryta varies soon after food from 15·23 grs. per 1000 grs. of urine, specific gravity 1033·9, to 9·45 grs. per 1000 grs. of urine, specific gravity 1029·3. It varies long after food from 8·56 grs. per 1000 grs. of urine, specific gravity 1027·6, to 7·07 grs. per 1000 grs. of urine, specific gravity 1025·3.

II. As to the causes of variation—(*a*) as regards food; (*b*) as regards exercise.

(*a*) Food, whether animal or vegetable, causes an increase in the quantity of sulphate of baryta precipitated, but the difference between animal and vegetable food is not well-marked.

(*b*) Exercise appears slightly to increase the amount of sulphates in the urine, but the increase is not so marked as it is after food.

III. As to the effect of medicines on the sulphates,—(*a*) sulphuric acid; (*b*) sulphur; (*c*) sulphates.

(*a*) Thirteen drops of strong sulphuric acid in one of three experiments increased the sulphates in the urine. Twenty drops of the same acid gave no positive proof.

Seventeen drachms of dilute sulphuric acid, taken in eight days, gave no positive proof of an increase of sulphates in the urine on the ninth day.

But when the whole quantity of urine passed in twenty-four hours for three successive days, when no sulphuric acid had been taken, was compared with the whole quantity passed in twenty-four hours, when half an ounce of dilute sulphuric acid was taken, then for three successive days that the experiment was made, the increase of sulphates was most marked. And from this it is certain, that when a large quantity of dilute sulphuric acid is taken the sulphates are increased in the urine. When small quantities of sulphuric acid are taken the effect on the sulphates in the urine is not detectable.

(*b*) 61½ grains of dry sulphur, taken for five days, gave an average amount of sulphates in the urine, both before and after food, higher than when no sulphur was taken. But with this dose the increase, though decided, was not considerable.

(*c*) 123½ grains of sulphate of potash produced a marked increase from two to four hours afterwards. In seven hours the increase was more marked. Sulphate of magnesia had a similar effect. The increase in the sulphates in the urine was much more evident than when sulphur or sulphuric acid were taken.

The result of these experiments is—

1st. That the sulphates in the urine are much increased by food, whether it be vegetable or animal.

2nd. Exercise does not cause a very marked increase in the sulphates.

3rd. Sulphuric acid when taken in large quantity increases the sulphates in the urine. In small quantity, even when long continued, no effect is manifest.

4th. Sulphur when taken does increase the sulphates in the urine.

5th. Sulphate of potash and sulphate of magnesia produce the most marked increase of the sulphates in the urine.

XIV. *Appendix to a paper on the Variations of the Acidity of the Urine in the state of Health.*

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Received May 7,—Read May 24, 1849.

On the Influence of Caustic Potash, Tartaric Acid, and Tartrate of Potash on the Acidity of the Urine.

In a paper on the variations of the acidity of the urine in the state of health, I have, in the third section, given the effect of dilute sulphuric acid; in this Appendix I purpose to show the influence of other medicines on the variations of the acidity of the urine.

III. (*b.*) The effect of caustic potash on the acidity of the urine was examined.

The caustic potash of pharmacy varying much in its specific gravity from 1060 downwards, and in the proportion of carbonate of potash which it contains, some caustic potash perfectly free from carbonate, and of specific gravity 1072, containing, by Dr. Hofmann's analysis, from 6·20 to 6·29 per cent. of potash, was used for the following experiments. It was taken in distilled water.

The day before the alkali was begun the variations of the acidity of the urine were first determined for the purpose of comparison.

The first day two drachms and a half of caustic potash were taken; the same quantity the second day, and the third day three drachms were taken. Thus eight drachms were taken in three days; and the following day, when no caustic potash was taken, the variations of the acidity of the urine were again determined for the purpose of further comparison.

(20.) The day previous to the alkali. Breakfast on eggs, meat, coffee and bread, at $8^h\ 5^m$ A.M. Dinner on mixed diet at 6^h P.M. Water passed at $7^h\ 15^m$ A.M. was thrown away.

	h	m	Spec. gr.	Acidity per 1000 grains of urine.	Appearance.
Water passed at	8	5 A.M.	=1023·2	=+25·41 measures.	Thick from urates.
Water passed at	9	30	=1022·8	=+12·61	Thick from urates.
Water passed at	10	45	=1024·1	=− 4·88	Clear.
Water passed at	11	35	=1027·0	=−13·63	Clear.
Water passed at	12	35 P.M.	=1026·5	=− 3·89	Clear.
Water passed at	2	30	=1025·0	=+14·72	Clear.
Water passed at	4	15	=1024·4	=+20·49	Clear.
Water passed at	6	0	=1026·6	=+31·17	Thick from urates.
Water passed at	9	0	=1028·6	=+18·47	Clear.
Water passed at	11	0	=1028·0	=−11·67	Clear.

From this it appears that the variations are nearly alike to those which were

observed six months previously; and it is worth noting that for six weeks before this experiment very little walking exercise was taken.

(21.) The following day breakfast was as before, at $8^h\ 10^m$ A.M. Dinner at 6^h P.M. One drachm and a half of liquor potassæ was taken in distilled water between 11^h A.M. and 1^h P.M., and another drachm between 3^h and $3^h\ 30^m$ P.M., both in as little water as possible.

	h	m	Spec. gr.	Acidity per 1000 grs. of urine.	Appearance.
Water passed at	7	0 A.M.	=1019·0	=+14·71 measures.	Clear.
Water passed at	8	10	=1026·1	=+20·46	Thick from urates.
Water passed at	9	30	=1025·0	=+12·68	Clear.
Water passed at	11	0	=1025·8	0	Clear.
Water passed at	1	0 P.M.	=1025·6	=− 6·82	Clear.
Water passed at	3	0	=1024·1	=+10·74	Clear.
Water passed at	3	40	=1022·0	=+ 9·78	Clear.
Water passed at	6	0	=1019·2	=+10·78	Thick from urates.
Water passed at	9	0	=1032·0	=+11·62	Clear.
Water passed at	11	15	=1028·7	=−28·19	Thick from phosphates.
Water passed at	6	30 A.M.	=1024·3	=+ 1·95	Clear.
Water passed at	7	40 lost.			

(22.) The following day. Breakfast at $8^h\ 40^m$ A.M. Dinner at 6^h P.M. Liquor potassæ a drachm and a-half from 10^h to $10^h\ 30^m$ A.M. and one drachm at 3 P.M. In as little distilled water as possible.

Water passed at	8	40	=1024·4	=+12·69 measures.	Clear.
Water passed at	9	50	=1024·6	=+11·71	Thick from urates.
Water passed at	10	50	=1021·5	=+ 1·95	Clear.
Water passed at	11	55	=1024·5	0	Clear.
Water passed at	2	45 P.M.	=1025·3	=− 1·95	Clear.
Water passed at	4	10	=1025·7	=+ 9·74	Clear.
Water passed at	6	0	=1027·1	=+14·59	Thick from urates.
Water passed at	8	40	=1033·3	=+14·51	Thick from urates.
Water passed at	11	30	=1031·5	=+ 9·70	Thick from urates.

(23.) The following day. Breakfast at $8^h\ 10^m$ A.M. Dinner at $6^h\ 30^m$ P.M. A drachm and a-half of liquor potassæ was taken at $9^h\ 30^m$ A.M., a drachm at 10^h A.M., and a drachm at $11^h\ 15^m$ A.M.

Water passed at	7	0 A.M.	=1020·2	=+11·76 measures.	Clear.
Water passed at	8	10	=1017·3	=+ 3·93	Clear.
Water passed at	9	20	=1020·0	=+ 4·94	Thick from urates.
Water passed at	10	30	=1010·0	=− 3·96	Clear.
Water passed at	11	15	=1019·7	=−11·76	Clear.
Water passed at	12	5 P.M.	=1019·8	=−19·61	Clear.
Water passed at	12	35	=1022·6	=−18·58	Clear.
Water passed at	2	45	=1022·6	=+ 2·93	Clear.
Water passed at	3	45	=1024·0	=+ 8·79	Clear.
Water passed at	5	20	=1024·4	=+10·73	Thick from urates.
Water passed at	6	30	=1025·3	=+11·70	Thick from urates.

	h	m		Spec. gr.	Acidity per 1000 grs. of urine.	Appearance.
Water passed at	9	10	P.M.	=1029·4	=+ 4·85 measures.	Thick from urates.
Water passed at	11	45		=1030·6	=−16·50	Clear.
Water passed at	6	55	A.M.	=1020·3	=− 0·98	Clear.
Water passed at	8	15		=1023·2	=− 2·93	Clear.

(24.) The following day. Breakfast at $8^h\ 15^m$ A.M. Dinner at $6^h\ 30^m$ P.M. Food as before. No alkali was taken.

Water passed at	10	0	=1025·0	=− 4·88 measures.	Clear.
Water passed at	11	25	=1025·1	=−18·53	Iridescent scum.
Water passed at	12	45 P.M.	=1025·0	=− 9·75	Clear.
Water passed at	2	50	=1024·2	=+11·71	Clear.
Water passed at	4	15	=1025·0	=+15·60	Clear.
Water passed at	6	30	=1027·0	=+21·42	Thick from urates.
Water passed at	10	45	=1030·2	=+10·67	Thick from urates.
Water passed at	6	30 A.M.	=1014·5	=+ 4·92	Clear.
Water passed at	8	10	=1022·2	=+ 9·88	Clear.

The result of these experiments is easily seen in Table XXI. It follows therefrom that liquor potassæ, taken in large doses, produces a decided effect in diminishing the acidity of the urine.

It by no means renders the urine constantly alkaline, and its effect on the urine seems rapidly to pass away. Notwithstanding the large quantity of liquor potassæ taken, the influence of food appears very evident; before each meal the acidity was highest; after each meal the alkalescence was greatest.

The acidity of 1000 grains of urine was rarely more than sufficient to neutralize one grain of dry and pure carbonate of soda; and the alkalescence was more than equal to a grain and a half of carbonate of soda in 1000 grains of urine.

The conclusion from these experiments is, that an ounce of liquor potassæ taken in three days does not counteract or conceal the influence of the stomach on the reaction of the urine.

III. (*c.*) The effect of tartaric acid on the acidity of the urine was then examined. Some splendid crystals of tartaric acid were given to me by Mr. Morson. These were dried, reduced to a fine powder and heated in a water-bath until they ceased to lose weight; a weighed quantity was dissolved in distilled water.

(25.) The first day for comparison no tartaric acid was taken. Breakfast at $8^h\ 45^m$ A.M. Dinner at $6^h\ 10^m$ P.M. Mixed diet.

	h	m		Spec. gr.	Acidity per 1000 grs. of urine.	Appearance.
Water passed at	7	45	A.M.	thrown away.		
Water passed at	8	45		=1025·4	=+19·50 measures.	Thick from urates.
Water passed at	9	45		=1025·0	=+13·65	Thick from urates.
Water passed at	10	45		=1022·7	=− 2·93	Clear.
Water passed at	12	45	P.M.	=1027·5	=− 8·75	Clear.
Water passed at	2	55		=1027·1	=+ 7·79	Clear.
Water passed at	6	10		=1025·7	=+26·32	Thick from urates.

	h m	Spec. gr.	Acidity per 1000 grs. of urine.	Appearance.
Water passed at	8 35 P.M.	=1032·3	=+19·37 measures.	Thick from urates.
Water passed at	10 30	=1031·9	=+14·53	Thick from urates.
Water passed at	6 40 A.M.	=1023·8	=+19·53	Clear.

For the three following days tartaric acid was taken. The first day forty-two grains of dry, pure tartaric acid, in two ounces of distilled water, at $11^h\ 40^m$ A.M. Forty-two grains more at $12^h\ 40^m$ P.M. In all, eighty-four grains. It did not act on the bowels as an aperient, but it caused pain in the bowels from about three hours after it was taken. It produced no pain when first taken into the stomach.

(26.) Breakfast as before, at $8^h\ 10^m$ A.M. Dinner as before, at $6^h\ 30^m$ P.M., eighty-four grains of tartaric acid being taken.

Water passed at	8 10 A.M.	=1025·3	=+24·38 measures.	Thick from urates.
Water passed at	10 0	=1026·2	=+13·64	Thick from urates.
Water passed at	11 15	=1029·1	=− 7·77	Clear.
Water passed at	12 55 P.M.	=1027·9	0	Clear.
Water passed at	2 30	=1027·1	=+23·36	Clear.
Water passed at	4 40	=1027·4	=+25·30	Cloudy urates.
Water passed at	6 30	=1030·4	=+32·99	Thick from urates.
Water passed at	8 40	=1033·1	=+36·79	Thick from urates.
Water passed at	11 40	=1033·0	=+ 7·74	Thick from urates.
Water passed at	6 50 A.M.	=1022·2	=+17·60	Clear.

(27.) The following day. Breakfast as before, at $8^h\ 10^m$ A.M. Dinner at $6^h\ 35^m$ P.M. Tartaric acid, fifty-four grains dry and pure, in two ounces of distilled water, at 11^h A.M.; fifty-four grains, in two ounces of water, at $12^h\ 15^m$ P.M.; in all 108 grains. This day the dinner was more and longer than usual.

Water passed at	8 10	=1026·0	=+23·33 measures.	Thick from urates.
Water passed at	9 30	=1021·5	=+14·68	Thick from urates.
Water passed at	10 10	=1020·6	0	Clear.
Water passed at	11 0	=1025·8	=− 9·74	Clear.
Water passed at	12 15 P.M.	=1026·4	0	Clear.
Water passed at	2 15	=1026·2	=+16·56	Clear.
Water passed at	3 15	=1025·0	=+23·41	Clear.
Water passed at	5 30	=1024·8	=+25·37	Clear.
Water passed at	6 35	=1027·0	=+31·15	Clear.
Water passed at	11 30	=1034·0	=+19·43	Thick from urates.
Water passed at	6 50 A.M.	=1025·4	=+16·58	Clear.

(28.) The following day. Breakfast as before, at $8^h\ 15^m$ A.M. Dinner moderate, mixed diet, at $6^h\ 50^m$ P.M. At 11^h A.M., tartaric acid, fifty-four grains in two ounces of water. At $11^h\ 40^m$ A.M. fifty-four grains of acid; at $12^h\ 40^m$ P.M. fifty-four grains; in all 162 grains. No pain in the abdomen until 3^h P.M., then much pain for an hour. Less pain for another hour, then all the pain went away. No action of the acid on the bowels.

	h m	Spec. gr.	Acidity per 1000 grs. of urine.	Appearance.
Water passed at	8 15 A.M.	=1026·0	=+21·44 measures.	Thick from urates.
Water passed at	9 50	=1024·2	=+ 0·97	Clear.
Water passed at	10 40	=1024·9	=−28·29	Thick from phosphates.
Water passed at	11 40	=1024·4	=−23·42	Thick from phosphates.
Water passed at	12 40 P.M.	=1023·7	=+ 3·90	Clear.
Water passed at	1 15	=1023·5	=+ 9·77	Clear.
Water passed at	2 25	=1024·7	=+22·44	Clear.
Water passed at	3 15	=1023·4	=+24·42	Clear.
Water passed at	5 5	=1019·4	=+26·48	Clear.
Water passed at	6 50	=1025·3	=+29·26	Clear.
Water passed at	11 35	=1030·6	=+17·46	Thick from urates.
Water passed at	6 20 A.M.	=1025·0	=+ 5·85	Clear.
Water passed at	8 15			

(29.) The following day. Breakfast at $8^h\ 15^m$ A.M. Dinner at 6^h P.M. Food as before. No tartaric acid was taken.

Water passed at	8 15	=1026·4	=+21·43 measures.	Thick from urates.
Water passed at	10 15	=1025·4	=+ 6·82	Clear.
Water passed at	11 20	=1024·7	=−13·66	Clear.
Water passed at	12 35 P.M.	=1025·5	=− 7·80	Clear.
Water passed at	2 40	=1026·0	=+14·61	Clear.
Water passed at	6 20	=1028·6	=+26·23	Clear.
Water passed at	11 25	=1031·0	=+ 5·81	Thick from urates.
Water passed at	6 45 A.M.	=1024·6	=+10·72	Clear.
Water passed at	8 10	=1025·9	=+14·62	Clear.

The result of these experiments is easily seen in Plate XXII. It follows that tartaric acid in large doses does produce a decided effect on the acidity of the urine; but it did not render the urine constantly acid during the three days that the experiment lasted.

The first day on which the acid was taken, the urine was much more concentrated than on the two other days, and hence the effect of the smaller dose of acid appears more evident than the larger.

The influence of the state of the stomach is very apparent. Before each meal the acidity is greatest. After food, notwithstanding the tartaric acid, the acidity is diminished.

The alkalescence of the urine was rarely so much as to equal one grain of carbonate of soda in 1000 grains of urine; whilst the acidity of 1000 grains of urine for the most part required about two grains of carbonate of soda to make its reaction neutral.

The conclusion from these experiments is, that 354 grains of dry and pure tartaric acid, taken in three days, increases the acidity of the urine; but in that time it does not render the effect of the stomach on the reaction of the urine less apparent than when no acid was taken.

III. (*d.*) The effect of tartrate of potash on the acidity of the urine was then examined. Some well-crystallized tartrate of potash was dried, reduced to a fine powder and dissolved in distilled water. The solution was neutral to test-paper.

(30.) The first day, for comparison, no tartrate of potash was taken. Breakfast at $8^h\ 15^m$ A.M. Dinner at 6^h P.M. Mixed diet. Water passed at $6^h\ 45^m$ A.M. thrown away.

	h m	Spec. gr.	Acidity per 1000 grs. of urine.	Appearance.
Water passed at	8 25 A.M.	=1023·3	=+21·49 measures.	Clear.
Water passed at	9 40	=1024·4	=+17·57	Clear.
Water passed at	10 50	=1027·0	=− 9·73	Clear.
Water passed at	12 56 P.M.	=1027·2	=+ 6·81	Clear.
Water passed at	3 10	=1025·7	=+23·39	Clear.
Water passed at	5 55	=1028·2	=+28·20	Clear.
Water passed at	10 40	=1034·4	=+18·36	Thick from urates.
Water passed at	6 15 A.M.	=1025·4	=+16·58	Clear.

For the following days tartrate of potash was taken. The first day two drachms of dry and pure tartrate of potash were taken, dissolved in two ounces of distilled water, at 9^h A.M. The same quantity was taken at $10^h\ 25^m$ A.M.; and one drachm of tartrate of potash was taken in one ounce of water at $2^h\ 30^m$ P.M. This last, on an empty stomach, caused slight nausea for twenty minutes. In all, then, on this day five drachms of tartrate of potash were taken in five ounces of distilled water. The bowels were not acted on by the saline.

(31.) The breakfast was at $8^h\ 10^m$ A.M. Dinner at $6^h\ 30^m$ P.M. Mixed diet.

Water passed at	8 10	=1026·4	=+23·38 measures.	Thick from urates.
Water passed at	9 30	=1022·4	=+ 2·93	Clear.
Water passed at	10 30	=1024·5	=−29·29	Cloudy from phosphates.
Water passed at	11 30	=1023·7	=−31·16	Cloudy from phosphates.
Water passed at	12 20 P.M.	=1021·4	=−14·68	Slight cloudiness from phosphates.
Water passed at	2 25	=1025·8	=+ 4·87	Clear.
Water passed at	4 5	=1027·5	=− 4·86	Clear.
Water passed at	6 30	=1033·3	=+24·19	Clear.
Water passed at	8 55	=1036·5	=+21·22	Thick from urates.
Water passed at	10 45	=1028·4	=−39·86	Thick from phosphates.
Water passed at	6 30 A.M.	=1027·0	=−14·60	Cloudy from phosphates.

(32.) The following day. Breakfast as before, at $8^h\ 10^m$ A.M. Dinner at $6^h\ 45^m$ P.M. Three drachms of tartrate of potash in four ounces of water, at $2^h\ 10^m$ P.M. caused slight nausea, and no action of the bowels.

Water passed at	8 10	=1030·2	=− 9·70 measures.	Clear.
Water passed at	9 30	=1026·2	=−19·49	Thick from phosphates.
Water passed at	11	=1024·9	=−27·31	Thick from phosphates.
Water passed at	12 30 P.M.	=1027·9	=− 5·83	Cloudy from phosphates.
Water passed at	2 10	=1028·8	=+23·32	Clear.
Water passed at	3 30	=1025·7	=−18·52	Clear.
Water passed at	5 10	=1025·1	=−10·73	Clear.
Water passed at	6 45	=1031·0	=+19·39	Clear.
Water passed at	9	=1034·1	=− 7·73	Clear.
Water passed at	10 45	=1026·3	=−37·02	Thick from phosphates.
Water passed at	6 20 A.M.	=1027·8	=− 4·86	Clear.

(33.) The following day. Breakfast as before, at 8 A.M. Dinner at $6^h\ 45^m$ P.M. Two drachms of tartrate of potash in four ounces of distilled water, at $2^h\ 45^m$ P.M. caused the slightest nausea and no action of the bowels.

	h	m		Spec. gr.	Acidity per 1000 grs. of urine.	Appearance.
Water passed at	8			=1031·8	=+ 4·84 measures.	Clear.
Water passed at	9	45		=1026·7	=−22·42	Thick from phosphates.
Water passed at	11	45		=1025·9	=−28·26	Thick from phosphates.
Water passed at	1		P.M.	=1027·4	=+ 4·85	Clear.
Water passed at	2	45		=1030·9	=+29·10	Cloudy from urates.
Water passed at	3	20		=1026·6	=− 7·79	Clear.
Water passed at	3	50		=1026·2	=−17·54	Clear.
Water passed at	4	50		=1027·8	=+11·67	Clear.
Water passed at	6	45		=1032·8	=+23·23	Clear.
Water passed at	9	25		=1036·5	=+ 9·64	Very thick from urates.
Water passed at	11	45		=1029·6	=−33·99	Very thick from phosphates.
Water passed at	5	55	A.M.	=1021·5	=−14·68	Cloudy from phosphates.

(34.) The following day. Breakfast as before, at $8^h\ 5^m$ A.M. Dinner at $6^h\ 55^h$ P.M. At $2^h\ 30^m$ P.M. three ounces of distilled water without any tartrate of potash were taken.

Water passed at	8	5	=1028·5	=+ 8·75 measures.	Clear.
Water passed at	9	20	=1021·3	=− 5·87	Clear.
Water passed at	11		=1020·0	=−31·37	Thick from phosphates.
Water passed at	12	45 P.M.	=1025·4	=−20·48	Cloudy from phosphates.
Water passed at	2	30	=1026·3	=+ 9·74	Clear.
Water passed at	3	40	=1024·3	=+23·43	Clear.
Water passed at	5	25	=1026·3	=+26·30	Clear.
Water passed at	6	55	=1028·4	=+31·11	Clear.
Water passed at	9	5	=1032·2	=+27·12	Thick from urates.
Water passed at	11	25	=1033·2	=+23·22	Thick from urates.
Water passed at	6	20 A.M.	=1026·5	=− 0·97	Cloudy from phosphates.
Water passed at	8	5	=1026·5	=+17·53	Clear.

(35.) Breakfast the following day at $8^h\ 5^m$ A.M. Dinner at $6^h\ 30^m$ P.M. At $2^h\ 30^m$ P.M. thirty grains of pure fused nitrate of potash were taken dissolved in three ounces of distilled water.

Water passed at	9	35	=1027·1	=+ 8·76 measures.	Clear.
Water passed at	11	20	=1028·9	=−22·35	Thick from phosphates.
Water passed at	12	40 P.M.	=1028·0	=− 2·92	Clear.
Water passed at	2	30	=1025·8	=+21·44	Clear.
Water passed at	3	10	=1024·6	=+23·42	Clear.
Water passed at	3	55	=1025·4	=+27·30	Clear.
Water passed at	5		=1027·2	=+31·15	Clear.
Water passed at	6	30	=1029·5	=+33·02	Clear.

It follows from these experiments, which are easily seen in Plate XXIII., that the influence of tartrate of potash is most decided. In five-and-thirty minutes after two

drachms of tartrate of potash were taken, dissolved in four ounces of distilled water, the urine was found alkaline, but in two hours the urine was again acid: the first effect on the urine had ceased to be very evident. That this was not caused by mere irritation of the stomach is seen by nitre and distilled water producing no similar effect. The influence of the tartrate of potash became again evident after the next meal, when the decrease in the acidity of the urine was much greater than when no tartrate of potash was taken.

From the high specific gravity of the urine after the tartrate, it is probable that undecomposed tartrate of potash passes off in the urine, and from the height to which the acidity rises when the medicine is taken, it seems possible that the tartaric acid is not decomposed but separated from the base *in transitu*; but on this point further experiments are requisite.

When much larger doses of tartrate of potash were taken, the rise and fall of the acidity of the urine before and after food were still distinctly evident.

The conclusions from these experiments regarding the effect of medicines on the acidity of the urine are—

(*b.*) That liquor potassæ taken in large doses does lessen the acidity of the urine. One ounce of liquor potassæ taken in three days hindered the acidity of the urine from rising before food to the height it otherwise would have done, but it by no means made the urine constantly alkaline, nor did it hinder the variations produced by the state of the stomach from being very evident.

(*c.*) That tartaric acid in large doses does increase the acidity of the urine. 354 grains of dry pure tartaric acid, dissolved in water, taken in three days, caused the acidity of the urine before food to rise considerably higher than it otherwise would have done; but this quantity of acid was not sufficient to hinder the urine passed a few hours after food from being alkaline. This quantity of tartaric acid therefore in this time does not produce so much effect on the reaction of the urine as the stomach does.

(*d.*) That tartrate of potash in large doses produces the most marked effect on the alkalescence of the urine. 120 grains of pure dry tartrate of potash dissolved in four ounces of distilled water made the urine alkaline in thirty-five minutes. In two hours the alkalescence had disappeared, but after the next meal the effect of the tartrate of potash was again apparent.

Ten drachms of tartrate of potash taken in three days produced but little, if any, effect on the acidity of the urine after it had been omitted for twenty-four hours.

Description of the Plates.

PLATE XVI.

The variations of the acidity of the urine during seventy-two hours when a mixed diet was taken.

PLATE XVII.

The comparison of the variations of the acidity of the urine on two mornings, on the first of which no breakfast was taken, and on the second a mixed diet.

PLATE XVIII.

The variations of the acidity of the urine during seventy-two hours when animal food only was taken.

PLATE XIX.

The variations of the acidity of the urine during seventy-two hours when vegetable food only was taken; at the end of that time animal food only was taken, and for eight hours afterwards the acidity of the urine is given in this Plate.

PLATE XX.

The variations of the acidity of the urine during seventy-two hours when nine drachms of dilute sulphuric acid and mixed diet were taken.

PLATE XXI.

The variations of the acidity of the urine during 120 hours. In the first twenty-four hours no liquor potassæ was taken; in the following seventy-two hours upwards of an ounce of liquor potassæ was taken with a mixed diet, and for the last twenty-four hours no liquor potassæ was taken.

PLATE XXII.

The variations of the acidity of the urine during 120 hours. For the first twenty-four hours no tartaric acid was taken; in the following seventy-two hours 354 grains of dry and pure tartaric acid were taken with a mixed diet, and for the last twenty-four hours no tartaric acid was taken.

PLATE XXIII.

The variations of the acidity of the urine during 132 hours. For the first twenty-

four hours no tartrate of potash was taken; in the following seventy-two hours ten drachms of tartrate of potash were taken with a mixed diet, and for the next twenty-four hours no tartrate of potash was taken, and in the last twelve hours thirty grains of nitre were taken.

PLATE XXIV.

The comparison of the variations of the acidity of the urine when different diets were taken.

PLATE XXV.

The comparison of the variations of the acidity of the urine when sulphuric acid, liquor potassæ, tartaric acid and tartrate of potash, and a mixed diet only, were taken.

XV. *Additional Observations on the Osteology of the Iguanodon and Hylæosaurus.*

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In the last memoir which I had the honour of placing before the Royal Society, allusion was made to the discovery of some remains of the Iguanodon that tended to elucidate the structure of certain parts of the skeleton of that gigantic terrestrial animal, which from the imperfect data previously obtained, had not been satisfactorily determined.

I now beg to submit to the consideration of the Society the results of a careful examination of these fossils, and of other illustrative specimens in the collections of my friends, in the hope that this addition to the previously recorded knowledge of the osteology of the Wealden Reptiles, will be found to possess considerable physiological interest and importance.

The fragmentary and isolated condition of the osseous relics found imbedded in the fluviatile deposits of the South-East of England, affords a sufficient excuse for error in the interpretation of a piece of bone, or in the reference of an entire bone to a particular genus or species. My own mistakes in this respect I shall unreservedly point out, and I would fain hope that other labourers in the same department of natural history, but of far higher authority, will not hesitate, after the noble example of the illustrious Cuvier, to make similar admissions; for it is only by substituting truth for error, and facts for hypotheses, that correct principles of palæontology can be established.

The fossils in my possession consist of several bones of the extremities and pectoral arch, and of cervical, dorsal, and caudal vertebræ of the Iguanodon, equal if not surpassing in magnitude any previously discovered; and portions of the sacrum of individuals of different ages; together with dermal and other bones of the Hylæosaurus, Goniopholis, &c. The recent acquisition of some of these relics excited in my mind a desire to renew the attempt to construct the skeleton of the colossal reptile whose remains were first brought to light by my early geological researches in Tilgate Forest. I therefore repaired to the British Museum, and by the kind permission of Mr. Konig, re-examined many of the fossils described in my former works. I also availed myself of the liberality of Capt. Lambart Brickenden, Mr. Baber, Mr. Saull, &c., to inspect their several collections, and chisel out and figure or describe such specimens as threw light on the especial object of my present inquiries.

In the difficult and tedious investigations necessary to arrive at any certain con-

clusions as to the distinctive characters of the vertebræ belonging to different parts of the spine of the same species of fossil reptile—in which there is no clue to guide us through the labyrinth but analogy—I was so fortunate as to obtain the invaluable aid of that profound anatomist and physiologist, Dr. A. G. Melville, without whose co-operation it would have been impossible for me, from the pressure of professional engagements, to have instituted the requisite comparison of the specimens with the corresponding bones of allied recent and fossil species; or to have arrived at the determination of the true place in the vertebral column of certain isolated vertebræ presenting remarkable dissimilarities in their characters, and which had formerly been assigned by myself and others to distinct genera of Saurians.

As the present communication may be regarded as supplementary to my former attempts to illustrate the osteological structure of the Wealden reptiles, I propose, for the convenience of reference, to notice the various subjects under review, in the order adopted in my memoir published in the Philosophical Transactions for 1841.

Iguanodon. *Angular Bone of the Lower Jaw.*—With the gigantic femora, tibiæ, and vertebræ, hereafter described, were found associated numerous fragments of large ribs, vertebral processes, &c., and a portion of a long arched bone of so peculiar a shape as to defy all my attempts to determine its place in the skeleton, till the sagacity of Mr. Waterhouse (of the British Museum) recognized its accordance with the angular bone of a reptile; an opinion which a careful comparison of the fossil with recent types has satisfactorily confirmed. The specimen is 10 inches in length, and proves to be the right angular bone of the lower jaw of a large Iguanodon; it exhibits the deep longitudinal channel, and the post-opercular notch, peculiar to that maxillary element in Saurians, but is not sufficiently perfect to afford an instructive delineation; the length of the jaw to which it belonged was probably from 3 to 4 feet.

Vertebral Column.—The structure of the middle dorsal and anterior caudal vertebræ, was first established by the figures and descriptions given in my various geological works, and by the references to these parts of the skeleton in the Maidstone specimen; for although the vertebræ in that celebrated fossil are more or less distorted by compression, their distinctive characters are not obliterated, but may be recognized by due attention.

The elaborate and critical examination of all the Saurian vertebræ from the Wealden collected by myself and others, given in the masterly reports on the British Fossil Reptiles by Professor Owen, undertaken and published at the expense of the British Association of Science since the appearance of my memoir in the Philosophical Transactions for 1841, has supplied many important diagnostic details of great value to the cultivator of this department of palæontology. But the determination of the cervical, anterior dorsal, lumbar, and terminal caudal, has not hitherto been satisfactorily accomplished. For although in my earlier attempts to interpret the mutilated and generally isolated relics of gigantic Saurian skeletons which were from time to time exhumed in the Wealds of the south-east of England, certain large vertebræ of dissimilar forms were vaguely assigned to the Iguanodon—

more from their constant collocation with undoubted bones of that reptile, and the absence of any remains of the extremities of other species or genera to which they could have belonged, than from any legitimate anatomical deductions—yet almost all these bones have since been referred to distinct genera by Professor Owen*.

Among the fossils lately obtained from the Isle of Wight, are certain cervical, anterior and middle dorsal, and posterior caudal vertebræ, which so closely approximate in their essential characters to the other elements of the spinal column of the Iguanodon, as to leave but little doubt that they belong to that animal. And although in the absence of any connected portions of the anterior part of the spine absolute certainty cannot be obtained, the close typical affinity of the bones in question supports this view of the subject, rather than that which assigns them to distinct genera of reptiles, of which no other less questionable vestiges have been discovered in the Wealden formation.

I will now briefly state the result of a careful examination and comparison of all the materials to which we could obtain access; the anatomical details, and the description of the essential osteological characters upon which our opinions are based, have been drawn up by Dr. Melville, and his subjoined report will, I doubt not, be regarded by the scientific palæontologist as the most valuable part of this memoir.

Cervical vertebræ, Plate XXVIII. figs. 4, 6.—In my Geology of the South-East of England† (published in 1833), several large convexo-concave vertebræ from Tilgate Forest are described as presenting the true lacertian type, being concave anteriorly, and convex posteriorly, as in the Iguana, Monitor, Crocodile, &c., and this statement is repeated in my memoir of 1841‡. But Professor Owen, from a more accurate examination of one of these bones (now in the British Museum), in which the posterior oblique processes remain, discovered that the relative position of this vertebra in the skeleton must have been the reverse of that which I had assigned to it; the *convexity being anterior* and the *concavity posterior*. A similar deviation from the ordinary Saurian structure had long since been detected by Cuvier in a fossil crocodilian found at Honfleur, and figured and described in the "*Ossemens Fossiles*" (tome v. p. 155); and which, though referred by Geoffroy to the genus *Steneosaurus*, has since been named by Von Meyer *Streptospondylus* (reversed spine); a most objectionable name, since the same character prevails in several fossil genera, as well as in many existing Mammalia. The fossil vertebræ from Tilgate Forest, above mentioned, are assigned by Professor Owen to the genus *Streptospondylus* of Von Meyer, as *S. major* §.

But notwithstanding this decision, and the adoption of Professor Owen's interpre-

* See Reports on British Fossil Reptiles, vol. for 1841, pp. 88–94. † Page 307.

‡ Philosophical Transactions, p. 141, Pl. IX. fig. 4.

§ British Association Reports, 1841, p. 91. The eminent author appears however to have entertained some doubts whether the appropriation was correct, and the vertebra in question might not belong to his genus "*Cetiosaurus*;" but he dismisses the suspicion with the remark, "that the general constancy of the vertebræ of the same Saurian in their antero-posterior diameter forbids the supposition of a vertebra 6 inches in length in the neck, being associated with one 3 inches in length in the back," p. 96.

tation of these vertebræ in my subsequent geological works*, yet I could not divest myself of the idea that this inference might be erroneous, from the fact that all the convexo-concave vertebræ of the Wealden were cervical; it was indeed this circumstance, and the extreme rarity of this type, which deterred the Rev. W. D. Conybeare and myself, at the very commencement of my exploration of the Wealden, from assigning them to the Iguanodon†.

The inspection of a large anterior dorsal vertebra of the convexo-concave system, recently obtained by me from the Isle of Wight (Plate XXVIII. fig. 5), first suggested to Dr. Melville the idea that this bone, as well as the cervicals above described, belonged to the Iguanodon; and he has spared neither time nor trouble to determine the correctness of this solution of the problem. To him, therefore, alone is due the credit of having first correctly interpreted the characters of this important part of the skeleton, should future discoveries confirm our present view of the subject.

The gradual transition from the anteriorly convex cervical vertebræ with their deep posterior concavity (see Plate XXVIII. fig. 4^a and fig. 4^b), to the plano-concave vertebræ of the posterior dorsal and lumbar regions, appears, at least in the absence of the only certain evidence—a naturally connected spinal column—to warrant the conclusion that all these vertebral elements are referable to the same gigantic herbivorous Saurian‡. If this opinion be correct, the adult Iguanodon must have approached in the structure of its vertebral column, as well as in its maxillary and dental organs and hinder extremities, to that of the Rhinoceros and other large pachyderms; for in them the convexo-concave type characterizes the cervical and anterior dorsal regions of the spine§.

Anterior dorsal vertebra, Plate XXVIII. fig. 5.—In this specimen from Sandown Bay, the convexity is relatively less than in the cervical, and appears to indicate a gradual transition to the flat or but slightly elevated face of the middle dorsal, as shown in the fine vertebra found at Brook Bay with some enormous bones of the extremities of an Iguanodon; see Plate XXIX. fig. 8‖.

* Medals of Creation, p. 725. Wonders of Geology, 6th edit. p. 414.

† See Geology of the South-East of England, p. 307.

‡ A reference to Cuvier's Oss. Foss., tome v. p. 156, will show that even in the typical form of the genus *Streptospondylus* the same disappearance of the convexo-concave character in the middle and posterior dorsals, takes place.

§ If the discrepancy in the relative proportions and configuration of the cervical, dorsal, and caudal vertebræ be regarded as presenting objections to this view, let it be remembered that in the spinal column of our domestic Mammalia an equal dissimilarity prevails; for example in the Ox, in which the cervical are convexo-concave, and the convexity gradually disappears in the posterior regions of the spine; and the bodies of the distal caudal, instead of being solid throughout as in the anterior vertebræ, *have a large medullary cavity in the centre*, as in the fossil reptile, called *Poikilopleuron*.

‖ In my memoir of 1841, a fragment of a vertebra, which Baron Cuvier supposed to be part of the atlas of an Iguanodon, is described as such; and the cast of the spinal canal in calcareous spar is regarded as that of the medulla oblongata (Philosophical Transactions, Plate IX. fig. 1). This specimen has since been cleared of the sandstone with which it was partially invested, and proves to be the neural arch of a crocodilian cervical vertebra.

Sacral and caudal vertebræ, Plate XXX.—The most important and novel announcement in relation to the osteology of the Wealden reptiles in Professor Owen's Reports, was the exposition of the structure of the sacrum in the three remarkable extinct genera of his order Dinosauria; namely, the Megalosaurus, Hylæosaurus, and Iguanodon; a peculiarity of mechanism which had escaped the penetration of all previous observers. No one appears to have suspected that in these reptiles the pelvic arch was composed of a greater number of anchylosed vertebræ than in the living Saurians; and that the position of the neural arches was transposed from its usual place over the middle of the body of the vertebra, to the ossified intervertebral spaces formed by the anchylosis of the contiguous vertebræ; the foramina for the transmission of the sacral nerves from the spinal chord being situated above and behind the middle of the body (see Plate XXX. figs. 15, 16)*.

Fragments of the pelvic arch, consisting of the body of one sacral vertebra, with a portion of the contiguous bones anchylosed to each extremity, are not uncommon in the Wealden deposits; and so long since as 1826, Sir R. Murchison transmitted to Baron Cuvier a specimen of this kind (from Loxwood in Sussex†), with several lumbar and caudal vertebræ. Upon these relics the illustrious founder of palæontology only remarked, that the united bodies of the vertebræ "seem to indicate that the animal to which they belonged made such feeble use of its tail that the caudal vertebræ were occasionally anchylosed together." Neither did the magnificent specimen of the sacrum of the Megalosaurus, consisting of a series of five united vertebræ, made known by the present Dean of Westminster in 1824, suggest the correct interpretation of this part of the skeleton of the Dinosaurians. The announcement of Professor Owen was therefore to me of especial interest, since it elucidated the nature of many fossils in my collection which had previously been undeterminable.

The present investigation rendering it necessary to acquire an accurate idea of the characters of the vertebræ composing the pelvic arch of the Iguanodon, I obtained permission of Mr. Saull to have the fine specimen of a sacrum in his museum (described in Report of Brit. Assoc. p. 131), more completely developed at my own expense, as its true characters were in some measure obscured by the coating of hard calcareous grit with which, as is generally the case with the Isle of Wight Wealden fossils, it was partially invested. This interesting and instructive relic is figured as it now appears in Plate XXVI.; half the natural size in linear dimension.

This sacrum consists of *six* anchylosed vertebræ (not of *five* as described in the Reports on Brit. Foss. Reptiles, p. 130), with the right iliac bone attached. The relative size and proportions of the several bones composing the sacral arch are now well displayed. The body of the first or anterior vertebra (Plate XXVI. 1) is large, strong, and expanded, forming a powerful buttress in front; the bodies of the two posterior vertebræ (Plate XXVI. 5, 6) are likewise large and strong; but the second, third, and fourth, are constricted laterally in the middle (Plate XXVI. 2, 3, 4), and

* See Reports on Brit. Foss. Reptiles, 1842, p. 105.

† Geological Transactions, vol. ii. (New Series), p. 105, Plate XV. figs. 4, 6.

are more slender than either the anterior or posterior; by this modification of the elements of the sacral arch, both lightness and strength were obtained.

A similar construction is present in every specimen of the sacrum that has come under my observation, whether of young and small, or of old and large individuals; in all, the same relative proportions in the size of the vertebræ are present, as in Mr. Saull's fossil.

A portion of the sacrum of a young Dinosaurian consisting of four vertebræ,—the two posterior and two of the middle series—recently discovered in Tilgate Forest and presented to me by Captain Lambart Brickenden, is represented of the natural size in Plate XXVII. This fossil beautifully exhibits the forms of the bodies of the vertebræ, and the attachment of the neural arches to the anchylosed intervertebral spaces. The vertebræ differ so much in their proportions and configuration from those in the fossil figured in Plate XXVI., as to render it doubtful whether this specimen may not be a portion of the sacral arch of the Hylæosaurus: this subject will be more fully considered by Dr. Melville in the subjoined report*.

Another highly interesting series of the sacral vertebræ, with four consecutive anterior caudals of the same reptile, found by Peter Martin, Esq., at Charlwood in Surrey, are figured in Plate XXX. figs. 15, 16, 17, one-fourth the natural size. The portions of the sacrum consist of the anterior, three middle, and one of the posterior vertebræ, all of which are more or less mutilated (Plate XXX. figs. 15, 16). The implantation of the neural arches in the intervertebral spaces, the coalescence of the expansion above, and the foramina for the transit of the sacral nerves (fig. 15, *z*), are well shown: and the relative size of the last sacral and first caudals is seen in the series of four anterior caudal vertebræ (fig. 17). The absence of a chevron bone at the junction of the two first caudals (fig. 17, *x*), and the presence of this element in the succeeding interspaces (fig. 17, *i*, *i*, *i*), seem to indicate that the first of this series is the second caudal; as the deep concavity of the posterior anchylosed sacral vertebra renders it probable that the anterior face of the first caudal—the bone which unites the tail to the pelvis—was more or less convex; as is the case in the Crocodile, Gavial, &c.†

Pelvis.—Of the pelvic bones, the *Iliac*, of which both the right and left are preserved in the Maidstone specimen, and the right Ilium in the sacrum figured in Plate XXVI., are alone determined. There are portions of large bones in my former

* Among the water-worn masses of bone so abundantly strewn along those parts of the southern shores of the Isle of Wight, which are bounded by cliffs of the Wealden strata, I had often met with specimens in which the body of a very large vertebra is anchylosed to one so disproportionately small, that I could not explain their origin, until Professor Owen's description of the structure of the sacrum suggested their true nature. These fossils are in fact one of the large vertebræ either of the anterior or posterior end of the sacrum united to one of the slender middle vertebræ. A specimen of this kind in the highly interesting collection of Mr. Barber, is of enormous size; the anterior face of the largest vertebra being 7½ inches by 6½ in diameter. This fossil is also interesting on another account, for on one side of the body of the largest vertebra there is an abnormal enlargement (or exostosis): I have observed similar bony tumours on the sides of the bodies of other vertebræ.

† See Wonders of Geology, sixth edition, p. 419.

collection which unquestionably belong to the pelvic region of some great Saurian, most probably of the Iguanodon, but at present all the elements of this part of the skeleton have not been found in a state sufficiently recognizable to admit of their positive identification.

Caudal vertebræ.—The characters of the anterior caudals are so well known that it is unnecessary to describe them; but on the somewhat angular caudals, originally referred by me to the Iguanodon, and subsequently ascribed to the *Cetiosaurus* by Professor Owen, and now restored to the former reptile by Dr. Melville, I will offer a few remarks. In the first place, in confirmation of the opinion that these vertebræ belong to the Iguanodon, I would especially call attention to the fact, that with the unquestionable Iguanodon sacrals found at Loxwood, and examined by Baron Cuvier (as previously mentioned, *ante*, p. 275), were several caudals belonging to the same individual, and these possess the angular form, and more or less grooved base, as may be seen by reference to the Geological Transactions, vol. ii. New Series, pl. 15. figs. 1, 3. I can vouch for the accuracy of the figures from having carefully examined the specimens at the time they were being drawn by that able artist, Mr. Scharf.

I would next call attention to the spine of the Hylæosaurus, which exhibits in the several modifications of its vertebræ, as great a discrepancy in the elements of the dorsal and caudal regions, as our proposed restoration of the spinal column of the Iguanodon. In the highly instructive specimen from the Weald of Sussex, represented on a small scale (one-sixth linear) in Plate XXXII. fig. 22, a nearly uninterrupted chain of vertebræ is preserved, commencing with the first caudals. The marked angular character of the middle and distal vertebræ is most obvious; and the difference between these bones and the anterior caudals, and the corresponding modifications in the form of the chevron bones, are as great as those presented by the vertebræ we have ascribed to the different regions of the spine in the Iguanodon.

If this chain of vertebræ of the Hylæosaurus had not been found in connection with unquestionable bones of that reptile, namely, the dermal scutes and spines, no one could have established their relation; and the tail of this Wealden reptile would have run the risk of being for ever separated from the body to which it originally belonged, and would probably have been honoured with a distinct generic appellation.

The chevron bones in the Hylæosaurus present a remarkable variation in form, as is shown in Plate XXXII. fig. 22. The most anterior (fig. 22 *g*) has a double head for articulation with the body of the vertebra; in the next variety (fig. 22 *f*) the two articulating facets are confluent as in the Iguanodon; in the distal (fig. 22 *e*) the chevron bones are so much elongated in a horizontal direction in a line with the axis of the body, as to be in contact with each other in the centre; this part of the tail must therefore have formed a very strong elastic subcylindrical chain or chord.

Pectoral arch.—I now arrive at the consideration of that part of the skeleton respecting which, happily, no controversy can arise, and that has been established by my own discoveries and investigations. By a reference to my former paper*, it

* Philosophical Transactions, 1841, Plate VIII. fig. 19.

will be seen that the clavicles of the Iguanodon were recognized from two of these bones occurring in the Maidstone specimen; and that a coracoid bone, 10 inches wide, was also ascribed to the same reptile*, from several examples having been found with undoubted bones of the Iguanodon: but the latter reference was only provisional, since there was no connecting link to unite this element to the other parts of the pectoral arch. A scapula, 18 inches long†, for a similar reason was placed in the same category; but with the precautionary remark, "that neither of the specimens was found in natural apposition or connexion with other portions of the skeleton, but only imbedded in the same mass of rock." I have often vainly attempted to find such a correspondence between the articulating facets of the coracoid and scapula above mentioned, as would warrant the conclusion that they originally belonged to the same genus of Saurians. By the fortunate discovery of a perfect scapula (Plate XXX. fig. 10) which fulfils these conditions, and can also be proved to belong to the Iguanodon, both the bones forming the shoulder-joint are now for the first time determined.

This specimen is delineated one-fourth the natural size in Plate XXX. fig. 10; when obtained it was firmly imbedded in the hard Tilgate sandstone, and broken into several pieces: I succeeded in extricating the whole from the rock, and in reuniting the dissevered parts, so as to demonstrate the perfect form of this most interesting fossil. It is the right scapula, and is 13 inches long, $5\frac{1}{4}$ inches wide at the humeral and 4 at the upper or spinal extremity; like that of the Crocodile it is slender, flat, and slightly arched; at the humeral end it becomes thick and expanded to form the apophysial surface that united with the coracoid, and the outer half of the glenoid cavity to receive the head of the humerus; it is flat and very thin at the upper or spinal end. This bone differs essentially from the scapula of the Iguanas, Monitors, &c., and approximates to that of the Crocodiles and Scinks; the minute scapula of the Chameleons presents the same simple character.

Upon placing this scapula in juxtaposition with a coracoid of the form assigned to the Iguanodon‡, it will be manifest that the two bones must have belonged to the same scapular arch; as is shown in Plate XXX. figs. 10 and 11. The close resemblance between this form of pectoral arch and that of the Hylæosaurus will be seen at a glance by reference to the figures of the latter§. The scapula of the Iguanodon differs from that of the Hylæosaurus in having the body more arched and slender, and the neck more contracted; and in the absence of the strong acromial ridge which characterizes the latter. The coracoid (Plate XXX. fig. 11) differs chiefly in its greater external convexity and inner concavity, and in the apophysial scapular surface being separated from the glenoid facet by a deep notch (Plate XXX. fig. 11 *e*) for the passage of vessels, instead of having a simple perforation as in the Hylæosaurus. In both these reptiles, however, there is a closer affinity in the structure of the pectoral arch, than I have observed between other extinct forms.

* Philosophical Transactions, 1841, Plate IX. fig. 11. p. 138.

† Ibid. Plate IX. fig. 10.

‡ Ibid. Plate IX. fig. 11.

§ Ibid. Plate X. fig. 8.

While examining the scapula above described, I was reminded of the fractured portions of two long flat bones in the Maidstone specimen which I had often in vain attempted to decipher. One of these bones* lies across the right femur, as shown in the annexed diagram (fig. 1). Upon repairing to the British Museum, the identity of these bones was immediately apparent; they prove to be the right and left scapulæ; consequently the coracoids above mentioned, which are adapted to this form of scapula, also belong to the Iguanodon†.

Fig. 1.

Part of the Maidstone Iguanodon.

1. Two metacarpal bones.
2. Four consecutive dorsal vertebræ.
3. A detached dorsal vertebra.
4. *Humerus.*
5. A detached rib.
6. The right femur.
7. *Scapula* lying across the shaft of the femur.
8. Distal end of the corresponding *Scapula.*
9. A detached dorsal vertebra.

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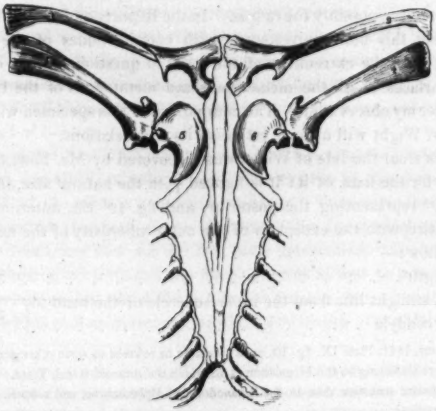
As the *clavicles, coracoids,* and *scapulæ,* are now determined, the structure of the pectoral arch of the Iguanodon may be regarded as established; and although the sternum is at present unknown, and the relative position of the several parts can only be conjectured, I have ventured to attempt the restoration of this important part of the skeleton of the extraordinary being on whose osteology I have bestowed so much time and labour. The annexed outline represents the arrangement which appears to me the most natural.

Fig. 2.

Restoration of the Pectoral Arch of the Iguanodon.



1. The right Clavicle.
2. The left Clavicle.
3. The right Scapula or Omoplate.
4. The left Scapula.
5. The right Coracoid.
6. The left Coracoid.

* Figured in Philosophical Transactions, 1841, Plate VIII. fig. 30.

† The Scapula with a long slender process extending from the head of the bone, which is figured in Philo-

Bones of the Extremities.

Humerus of the Iguanodon, Plate XXXI.—It may be worth remarking, that although numerous femora, tibiæ, and other bones of the hinder extremities were discovered in various localities, no certain remains of the fore-legs had occurred except the slender bones described by me as metacarpals*. Professor Owen† suggested that some of the bones in the British Museum, which I had considered as femora, might possibly be humeri, and the observations of a correspondent are quoted by him in corroboration of this opinion; but I feel confident that no one who will give sufficient attention to the subject, can for a moment admit the validity of the reasons adduced. The question however is now decided by the discovery of a bone found in the Wealden of the Isle of Wight, associated with other remains of the Iguanodon; and which is undoubtedly a humerus, because it cannot possibly be referred to any other part of the skeleton, and possesses all the essential characters of the principal bone of the anterior extremity of a gigantic reptile. Most fortunately, too, it can be proved to belong to the Iguanodon; for it is identical with a well-preserved, but much smaller bone, in the Maidstone specimen (Plate XXXI. fig. 20).

In my memoir of 1841, this last bone is figured‡, with the remark that "it probably belongs to the brachial extremity; it is imbedded near the two metacarpals, but I have not been able to determine its character satisfactorily." The relatively very small size of this bone appeared to be an insuperable objection to the regarding it as the humerus, and it therefore seemed to me more probable that it was one of the bones of the fore-arm, possibly the radius. In the Reports on British Fossil Reptiles§, it is stated that this bone corresponds with certain bones of the foot found at Horsham; but both the extremities of the fossil in question entirely differ from the articulating surfaces of all the metacarpals and metatarsals of the Iguanodon that have come under my observation. The comparison of this specimen with the humerus from the Isle of Wight will at once establish its true relations.

The humerus from the Isle of Wight was discovered by Mr. Fowlstone, to whom I am indebted for the loan of it: it is figured $\frac{1}{12}$th the natural size, in Plate XXXI. fig. 19; fig. 19^a representing the posterior, and fig. 19^b the anterior aspect. This fine bone is entire, with the exception of the outer tuberosity of the head; its dimensions are as follow:—

Greatest length	3 feet.
Length in a straight line from the inner tubercle of the head to the inner condyle	31½ inches.

sophical Transactions, 1841, Plate IX. fig. 10, must therefore be referred to some other genus of the Wealden reptiles; it may possibly belong to the Megalosaurus, in which the coracoid (Geol. Trans., vol. vi. pl. 43, fig. 3) is of a more complicated structure than in the Iguanodon and Hylæosaurus, and somewhat resembles that of the Iguanas or Varanians.

* Philosophical Transactions, 1841, Plate VIII. fig. 14.

† Reports on British Fossil Reptiles, 1841, p. 138.

‡ Philosophical Transactions, Plate VIII. fig. 5. § Page 140.

From the outer tubercle of the head to the external condyle . .	33 inches.
Circumference of the head	23½
——— round the condyles	21½
Circumference of the shaft at the deltoid crest.	19½
——— one-third from the distal extremity	16

The medullary cavity only extends to within one-third of the top of the bone; it is 3 inches in diameter: the greatest thickness of the wall of the shaft is 1 inch.

The head of the bone presents the usual posterior protuberance of the humerus in Lizards, but the epiphysis of this, as well as of the distal extremity, is wanting, as is the case in all the long bones of the Wealden reptiles. At about 3 inches from the top the ridge or crest for the insertion of the deltoid muscle (*d*) is considerably developed, and extends 15 inches down the shaft, which rapidly contracts below, and finally expands to form the condyloid extremity. The articular face of the latter (Plate XXXI. fig. 19^a) is divided into two nearly equal condyles; the inner or ulnar segment (*e*) is traversed by an anterior furrow, which is more strongly marked in the humerus of a younger individual (Plate XXXI. fig. 18^a *e*): the posterior or olecranal fossa (*g*) is simple, and somewhat deeper than the anterior. On the whole, the aspect of this humerus more closely corresponds with that of the Crocodiles than of the ordinary Lizards.

I have for many years possessed the head or proximal extremity and the lower or condyloid end of two humeri, which must have belonged to very young Iguanodons. The former is of a left humerus: it is 8 inches in circumference, and with the exception of the absence of the epiphysis, is remarkably perfect; it is identical with the large specimen, and is figured one-third its natural size, Plate XXXI. fig. 21. The specimen of the lower or distal end of a right humerus is represented, Plate XXXI. fig. 18; it beautifully displays the condyloid facet for articulation with the bones of the fore-arm. In all these fossils the medullary cavity is large, and extends to within about one-third of the top.

In the same plate (Plate XXXI. fig. 20) is given a figure of the humerus in the Maidstone specimen, one-sixth its natural size; the situation of this bone is pointed out in the outline* of the scapula and adjacent bones. Thus after the lapse of fifteen years two important elements of the skeleton of the Iguanodon contained in that most valuable fossil, are now for the first time determined. The small size of the humeri, as compared with that of the femora, seems at first to present an objection to this interpretation; but the difference is not greater than obtains in many other fossil Saurians†, as well as in recent Lizards. The length of the Maidstone humerus

* *Ante*, p. 279, fig. 1.

† "C'est un fait à peu près général que les membres antérieurs des reptiles crocodiliens et lacertiens sont plus courts et plus faibles que les postérieurs; chez quelques espèces la différence est très-prononcée. Mais nos reptiles fossiles des environs de Caen annoncent une disproportion beaucoup plus forte encore entre ces membres: le Pœkilopleuron, le Sténéosaurus de Quilly, les Téléosaurus, en fournissent la preuve. Ces derniers surtout avaient les membres antérieurs d'une excessive petitesse; les deux paires de membres différaient entre elles plus peut-être qu'elles ne diffèrent les Gerbilles et les Kangaroos."—Deslongchamps, *Mémoire sur le Pœkilopleuron Bucklandii*, p. 81.

is about 20 inches, that of the contiguous femur 33 inches; but as the latter is somewhat flattened and extended by compression, the difference is probably not more than one-third. The Isle of Wight humerus is 3 feet long; the largest femur I have seen is 4 feet 8 inches; the average size of the femur in the adult was probably about 4 feet; this bone therefore presents the same proportionate length as the Maidstone humerus.

Hinder extremities.—The femur, tibia, fibula, metatarsals, phalangeals, and ungueals, have long since been discovered and determined*; but the bones of the tarsus as well as of the carpus are still unknown. I should have passed over these parts of the skeleton without remark, but that some of the femora, tibiæ, &c. which I have recently obtained are of such enormous proportions, as to require notice in proof of the colossal size which some individuals must have attained.

In the course of last autumn I procured from the cliffs near Brook Point,—a locality well known to the British geologist from the fossil forest exposed at its base†,—portions of two corresponding femora, tibiæ, and several vertebræ, fragments of ribs, &c. of Iguanodons. The most entire bone is the left femur; it consists of the shaft from above the popliteal space to the root of the outer trochanter‡: the head and condyles are both wanting; the inner trochanter remains: the length of this fossil is 3 feet; circumference of the shaft 27 inches. The greatest thickness of the wall of the shaft is 2 inches; the diameter of the medullary cavity 5 inches by 3; in all the femora which I have examined the medullary canal extends from above the condyles to within one-third of the top of the bone§. Of the right femur, which from its correspondence in size is probably referable to the same individual as the left, two large portions of the shaft were alone obtained. Now if we take as a scale of proportions one of the large femora in the British Museum, the bone above described, if perfect, would give the following admeasurements:—

Total length	4 feet 8 inches.
Circumference of the head exclusive of the outer trochanter . . .	3 — 2
——————— the shaft at the base of the middle trochanter .	2 — 1
——————— the distal end round the condyles	3 — 6

One of the tibiæ found with the above, consists of about two-thirds of the shaft, with the distal or tarsal extremity nearly entire: the following are its dimensions:—

* Philosophical Transactions, 1841, Plate VIII.

† See my "Geological Excursions round the Isle of Wight," p. 277.

‡ Philosophical Transactions, 1841, Plate VIII. fig. 1, for an outline of the perfect form of the femur of the Iguanodon.

§ In this enormous bone the internal structure is beautifully preserved; sections properly prepared exhibit the peculiar form and proportions which Mr. Bowerbank considers to be characteristic of the reptilian type. That eminent microscopic observer has kindly favoured me with his measurements of the bone-cells in portions of this femur. The general average of the proportions of the length and diameter of the cells is as one to eleven and a quarter; the length being $\frac{1}{1\,1\frac{1}{4}}$ and the diameter $\frac{1}{1\,1\,1\,1\,5}$th of an inch.

Length along the middle of the shaft	27 inches.
Length to the distal inner process	32
Circumference of the distal or tarsal end	25
——— middle of the shaft	18
——— upper part	20½

Probable length of this tibia when entire, 4 feet.

A fragment of the shaft of a tibia found with the above, is 23 inches in circumference. The distal end of another tibia, from Sandown Bay, is 27 inches in circumference. As a contrast to these gigantic remains, I may state, that bones of the extremity occasionally occur so small, yet so compact, as to suggest the probability that they may belong to distinct species; but at present I have not been able to detect other characters which would warrant such an inference. A left femur in my possession, from Rusper in Sussex, is 14½ inches long; circumference of the shaft 6 inches; this therefore is but one-fourth the size of the specimen from Brook. The lower portion of a thigh-bone, which in the characters of its condyloid extremity entirely agrees with all the recognized femora of the Iguanodon, is but 3¼ inches in circumference round the condyles, and but 2½ round the shaft immediately above them; the total length of this femur, when entire, could not have exceeded 4½ inches.

In general the circumference of the shaft of the thigh-bone immediately below the base of the inner trochanter, is nearly equal to half the length of the entire bone; for example, the large right femur from Sussex in the British Museum, which is 3 feet 8 inches long, is 21 inches round the shaft. But there are exceptions to these proportions; thus the femur from Brook Point, presented by me to the Hunterian Museum of the Royal College of Surgeons, is relatively shorter, for it is only 3½ feet long, while the circumference of the shaft is 24 inches. The thigh-bone of the Maidstone fossil is of more slender proportions. The tibia is about one-tenth shorter than the corresponding femur; and the fibula somewhat shorter than the tibia. With the view of affording a general idea of the dimensions of the known parts of the skeleton of the Iguanodon, to which the largest femur in my possession belonged, the following list, calculated from the average size of numerous specimens, is subjoined: the length of the corresponding bones in the Maidstone fossil is added for comparison.

	Iguanodon from the Isle of Wight.	Maidstone Iguanodon.
Femur, length of	4 feet 8 inches.	2 feet 9 inches.
Tibia	4 — 1	2 — 6
Fibula	3 — 8	
Humerus	3 — 2	1 — 8
Clavicle	4 —	2 — 4
Scapula	3 — 4	2 — 1
Metacarpals	2 — 2	1 — 2
Ilium	3 —10	2 — 4
Metatarsals	1 —11	1 — 2
Ungueal bones	5¾	3½

Dermal bones, Plate XXXII.—Several dermal bones have been discovered since my last communication on this subject, some of which are clearly referable to the Hylæosaurus, while others may with great probability be assigned to the Iguanodon, from their obvious difference from those found associated with the bones of the former reptile. Some dermal spines or tubercles resembling that which I figured and described as the horn of the Iguanodon in my "Fossils of Tilgate Forest," have been found at Hastings, and in the Isle of Wight. One remarkably fine example of a conical dermal tubercle or horn, in which the core or base is ossified, was obtained from the Wealden at Ridgway near Weymouth, by Mr. SHIPP of Blandford, and several bones of the Iguanodon were found in the same locality; it is figured in Plate XXXII. fig. 24. Several somewhat angular bones, of coarse texture, 5 or 6 inches long, which resemble in form the spinous warts seen in the *Amblyrhynchus* and other Iguanidæ, have likewise been obtained from Sandown Bay. In the absence of proofs derived from direct connection or contiguity with known parts of the skeleton, it is useless to attempt appropriating these dermal appendages to particular Saurians. But in the case of the Hylæosaurus the dermal bones peculiar to that animal are easily recognizable; for not only have I found them in the typical specimen of this reptile discovered in 1832*, but likewise in the beautiful series of vertebræ already referred to†, Plate XXXII. fig. 22; in which the discoidal and oval scutes are situated on each side the spinous processes of the vertebræ.

The same fossil contains, at the anterior part, portions of large angular spines resembling those described in my former memoir‡. As the correctness of my opinion that the large flat spines in the first-discovered specimen of the Hylæosaurus were dermal, and extended down the back as a dorsal fringe, has been questioned by Professor OWEN§, I beg to state, that since my former communication I have submitted sections of one of these spines to microscopical examination, and if identity of internal structure be of any value, my interpretation is substantiated; for the same remarkable organization is present as in the admitted dermal scutes, namely, "straight spicular fibres decussating each other in all directions, and seeming to represent the ossified ligamentous fibres of the original corium‖."

Summary.—The facts described in this communication will, I trust, be regarded as a valuable addition to our knowledge of the osteological structure of one of the most remarkable herbivorous terrestrial quadrupeds that ever trod the surface of our planet. With the exception of the cranium, sternum, and the bones of the fore-arm, carpus, and tarsus, the entire skeleton may now be considered as determined. In the present memoir the pectoral arch and the arm are for the first time described

* Geology of the South-East of England, Pl. V.

† *Ante*, p. 277.

‡ Philosophical Transactions, 1841, p. 150, Plate X. figs. 1, 2, 3, 4.

§ See Reports on British Fossil Reptiles, 1841, p. 115.

‖ See Wonders of Geology, sixth edition, p. 438. Mr. BOWERBANK, Mr. WILLIAMSON, and other eminent microscopical observers, to whom I gave specimens of the spines, concur in the statement that the structure of these bones is identical with that of the dermal scutes, Plate XXXII. fig. 23.

and correctly assigned, and the true characters of the vertebral column demonstrated, so far as the data hitherto obtained afford the means of re-connecting its disjointed elements.

The physiological inferences resulting from this investigation confirm, in every essential particular, those which I had the honour to submit to the Society in my late memoir on the maxillary and dental organs of the Iguanodon. By the determination of the principal bone of the arm, we now discover that the fore-limbs of the colossal original were more reptilian in their relative proportions with other parts of the skeleton, than could *à priori* have been surmised. But this comparatively feeble development of the anterior extremities tends to confirm the opinion which I formerly advanced, that the fore-feet were long and slender, and served as prehensile instruments; while the hinder limbs and feet were strong and massive, as in the Hippopotamus.

Thus, after the lapse of more than a quarter of a century, I conclude my attempts to restore the skeleton of the gigantic Saurian, of whose former existence a few isolated and water-worn teeth were the sole known indications, when, in 1825, I ventured to communicate to the Royal Society, through my friend the late Davies Gilbert, Esq., P.R.S., "A Notice of the Teeth of an unknown Herbivorous Reptile discovered in the Strata of Tilgate Forest in Sussex."

19 *Chester Square, Pimlico,*
15th January, 1849.

Notes on the Vertebral Column of the Iguanodon.

By A. G. Melville, *M.D., Edin. M.R.C.S.*

The atlas and axis of this gigantic reptile have not hitherto been discovered, but we may expect, as in the corresponding vertebræ referred to the *Steneosaurus rostrominor* (G. St. Hilaire), the pleural complement of the axis to have a double attachment, above to the superior transverse process derived from the base of the neural lamina, and below to an exogenous tubercle—inferior transverse process—on the lower part of the centrum of the atlas, or in addition, to the contiguous portion of the axis. In the recent Crocodiles, the cervical rib of the axis is displaced from its own centrum, and has an upper and lower attachment to the odontoid process or true centrum of the atlas. It will be a matter of great interest to ascertain if in any of the extinct Crocodilidæ or Dinosauria, the rib-like processes of the atlas are attached to their proper centrum, and not displaced forwards on the hæmal element of the occipital vertebra, or so-called body of the atlas, as in the existing Crocodiles; a displacement which repeats the normal attachment of the ribs in fishes to the inferior or hæmal elements of the bodies of the vertebræ.

The posterior surface of the body of the axis must be deeply concave, as we shall presently see.

The large cervical vertebræ from the Wealden strata, with reversed convexo-concave joints (*Streptospondylus major*, O.), (Plate XXVIII. fig. 4), enter into the composition of the cervical region of the spinal column of the Iguanodon. We are forced to this conclusion by the following circumstances:—1st, an anterior dorsal vertebra (Plate XXVIII. fig. 5.) from the same deposits, with similar but less marked deviations in the form of the articular facets, and with a configuration of the neural arch, so far as perfect, identical with that existing in more posterior dorsal vertebræ with plano-concave joints, well-recognized as belonging to this great herbivorous reptile, links together these apparently discrepant vertebral types: 2ndly, the amount of variation here assumed is parallel to that which exists in its affine among the Crocodilidæ, the *Steneosaurus rostro-minor**; and similar changes in the form of corresponding articular facets occur in the spinal column of the Ruminants, Solipeds, and other Pachyderms: 3rdly, other alterations in the sculpturing of the neural arch of equal value with the modifications in the form of the articular aspects of the body, are concomitant with these changes in the different vertebræ just mentioned, and are equalled in kind and degree by those which occur in the series of neural arches of the spine in the recent Crocodiles: 4thly, these convexo-concave cervical vertebræ are found in such collocation with other well-determined bones and vertebræ of the Iguanodon as to leave no reasonable doubt of their belonging to that animal: 5thly, the number of these vertebræ of different ages and sizes in our collections is such as we might have expected on that supposition; and 6thly, if these be not the cervical vertebræ of the Iguanodon, we have the (assumed) *Streptospondylus major* with nothing but a neck, whilst the Iguanodon, as yet known, is wholly destitute of that region of the spine: is it not, therefore, more probable that the neck of the so-called Streptospondylus belongs of right to the Iguanodon, especially as the bones of that reptile, tested by the fortunate discovery of the Maidstone specimen, constitute the great majority of the osseous relics from the deposits of the Weald? in other words, the Iguanodon is the reptile *par excellence* characteristic of the Wealden formation.

The Streptospondylian form of the body of a vertebra can no more characterize a genus of Reptiles than the Amphicœlian or Cœlospondylian modifications; each is common to a group of species constituting not only distinct genera and families, but also orders and subclasses. Nay, the Streptospondylian type is not even persistent throughout the elements of the same spinal column; it disappears towards the middle of the dorsal region in the *Steneosaurus rostro-minor*, the best known example of this structure, and that in which it was first recognized by Baron Cuvier. The genus *Streptospondylus* of V. Meyer ought therefore to be abolished, and the residual generic appellation *Steneosaurus* (G. St. Hilaire) be retained to designate Cu-

* Vide Cuvier, Oss. Fossiles, vol. ix. 8vo edit.

VIER's first Gavial of Honfleur. The Amphicœlian and Procœlian forms are generally continued through the whole length of the vertebral column; the Streptospondylian modification in the last sacral replaces, and in the first caudal is superadded to, the Procœlian form of the vertebral bodies characteristic of the living Crocodiles.

In the Report on British Reptiles much stress is laid on the uniformity in length of the bodies of the same vertebral series in Reptiles; this indeed holds good within certain limits among the less complicated smaller existing Lacertæ, but will lead us into error if rigidly applied to the more highly organized extinct Saurians and Crocodiles. The relative length of the vertebra must always be taken exclusively of the articular convexity, whether that be in front or behind, as is the practice in stating the absolute length of the spine or of its individual regions. Deterred by the great length of these cervical vertebræ referred to the *Streptospondylus major*, when compared with the shortness of the dorsal or lumbar vertebræ assigned by him to the *Cetiosaurus brevis*, Professor OWEN was unwilling to associate them together as belonging to the spinal column of the same species, which, however, appears to be really the case, as I shall afterwards have occasion to demonstrate.

The body of the cervical vertebra, Plate XXVIII. fig. 4, though somewhat crushed, well displays the peculiar characters of this region of the spine. Its dimensions are as follow:—

	inches.
Length of body between the centres of the articular facets . . .	$3\frac{3}{4}$
Extreme length, including convexity	$5\frac{1}{2}$
Length of body (inferiorly), exclusive of convexity	$3\frac{1}{2}$
Height of body posteriorly	$3\frac{1}{2}$
Width of posterior concave surface	5
Extent from the extremity of one transverse process to the other .	9
Transverse diameter of the spinal canal	$1\frac{3}{4}$

The centrum (*a*) is depressed, and yields a subpentangular section with the apex below; it is broader than high, but the width is nearly equal to the length. The anterior articular facet (*a'*) is convex, the posterior (*a''*) deeply concave with thin edges; both have a wide oval contour. The lateral aspect presents a deep concavity beneath the root of the neural lamina, bounded inferiorly by a ridge (*e*) faint and expanding behind, but developed in its anterior third or half into a flat oblong facet (*parapophysis*), for articulation with the head of the rib. Below the transverse ridges the surfaces of the opposite sides, concave outwards, rapidly converge to a broad median carina widening behind, which does not appear to be developed downwards in front into a distinct spine as in Crocodiles. How much of the body is contributed by the expanded bases of the neural laminæ cannot be readily determined, the sutures being obliterated; from the great width of the vertebral foramen in the neck, it is most probable that they do not meet mesially, and exclude the centrum from entering into the composition of that foramen, as is the case in the dorsal region of the spine.

The neural lamina (*b*) contracts above its base, and again slightly expands ere it coalesces with its fellow, the posterior notch as usually being the deepest; a small tract of the body is also, as it were, left uncovered in front and behind to nearly as great an extent as in the lumbar vertebræ hitherto assigned to the *Cetiosaurus brevis*; this character therefore is of no value either generically or specifically. The spine (*neuracantha*) is represented only by a ridge contracting and subsiding towards the anterior edge of the neural arch. The strong sub-prismatic upper transverse process (*d*) (*plagiapophysis*) springs from the upper part of the neural lamina (*neuropoma*), and curves backwards, bending slightly downwards towards its outer extremity, which furnishes a large articular rounded surface for the tubercle of the rib. Internally it is cut away obliquely downwards and inwards for the lodgement of the posterior oblique process (*met-arthrapophysis*) which lies between it and the crown of the neural arch, resting on the oval articular facet (*f*) of the anterior oblique processes (*pro-arthrapophysis*), which is thus situated on the upper surface of the transverse process; those of opposite sides are widely separate, look towards each other, and are only inclined slightly towards the horizon, their inner margins being separated by a narrow groove from the sides of the neural laminæ.

The long, thick and compressed peduncles of the posterior oblique processes (*g*), spring from the hinder border of the neural arch on each side of the mesial line, and diverge as they pass backwards, projecting much beyond the articular cup of the body. Their section is ovate, the lower edge being the thickest; each is slightly twisted on its axis towards the extremity, which is bevelled off obliquely to the upper margin for the oval articular surface, looking downwards and slightly outwards.

We may conjecture that this vertebra is one of the most posterior cervical from the high origin of the transverse process, for in the series of five vertebræ behind the atlas and axis in the Crocodile, this process rises gradually from the base of the neuropome to the middle of its height, and reaches the crown of the neural arch at the third dorsal.

The large vertebra with a wedge-shaped body and convexo-concave articular facets, Plate XXVIII. fig. 5, we regard as one of the more anterior of the dorsal region of the spine; in it the inferior transverse process has abandoned the side of the centrum, and is placed on that of the neural lamina. In the first dorsal of the Crocodile, the perapophysis is still below the neuropomal suture; in the third and fourth, the corresponding surface is subdivided by that sutural line; and in the fifth it quits the centrum altogether, but is not placed on the side of the neural arch. No specimen has yet been met with of a dorsal vertebra belonging to the Iguanodon with the perapophysial surface or tubercle wholly or partially on the centrum, although that character may have been presented by the two or three first dorsal.

The anterior convexity (a') of the above-mentioned vertebra is much less developed than in the cervical, and the concavity behind (a'') is correspondingly shallow. The section of the body would present a deep triangular outline with the apex below

corresponding to a thick median crest. The body is constricted in the centre so that the sides are concave parallel to its axis, but convex vertically, owing to the great prominence of a broad longitudinal ridge, equivalent to that bearing the perapophysial surface in the cervical; above and below which there is also a deep concavity. The spinal canal (*j*) has a transversely oval outline, and enlarges considerably towards each extremity. The neural lamina (*b*) contracts suddenly, though slightly, and chiefly from behind forwards above its expanded base, so that the posterior notch is much the deeper; its external surface is impressed by a deep and rough irregular fossa (*l*) for the insertion of the head of the rib, bounded behind by a sharp prominent ridge ascending obliquely forwards from near the posterior and inferior angle of the base of the neuropome, and passing outwards on the under surface of the plagiapophysis (*d*). In front, this perapophysial surface (*l*) is defined by a thin margin arching backwards to meet the above-mentioned buttress-like ridge at the root of the transverse process, which is detached, but springs with an inclination upwards from the side of the spinal platform. The spinous, anterior, and posterior oblique processes, are unfortunately wanting; but the anterior oblique processes do not approximate to each other so closely as in the more posterior vertebræ, in which they are merely separated by the trenchant anterior edge of the spine; from this we may infer that the long peduncles of the met-arthropophyses in the cervical vertebræ have coalesced at their bases to support the more strongly developed spine, but that their apices bearing the articular facets are still separated by a wide notch, more or less filled up by the base of the neuracantha (*c*), which decreases in width as it extends forwards to the anterior edge of the neural arch; its line of attachment sweeping downwards at the same time from the excavation of the spinal platform in front for the reception of the oblique processes of the preceding vertebra. The expanded bases of the neural laminæ are defined by the direction of the superficial striæ, and doubtless coalesce more or less completely in the mesial line, commencing in front, to exclude the centrum from any share in the formation of the vertebral canal. The dimensions of this most instructive specimen are subjoined.

	inches.	lines.
Length of the body between the centres of the articular surfaces .	4	3
Greatest width of body	4	3
Greatest height of body	6	6
Antero-posterior diameter of neural lamina where narrowest . .	2	9
Width of spinal canal	1	9
Height of spinal canal	1	4

The next vertebra to be described, Plate XXIX. fig. 8, differs from that just mentioned, in the flatness of the anterior articular surface (*a'*), and in the almost complete obliteration of the posterior concavity (*a''*), in the less central constriction of the body, and in the absence of its inferior median ridge. Notwithstanding the situation of the perapophysial surface on the side of the neuropome, the above characters

all point to a more posterior position in the dorsal series; and we may suppose either that the anterior convexity of the body subsided much more rapidly than the head of the ribs changed its point of attachment, or that several vertebræ presenting a similar configuration of the neural arch, but with a progressively diminishing convexity, occurred at the anterior part of the dorsal region, which would indicate a less rapid transition between the different forms of the vertebræ, and consequently a greater number of them than in the Crocodiles, which might indeed have been expected in a herbivore with a bulky trunk, as shown by the huge ribs in the Mantellian collection.

The dimensions of this very perfect and interesting fossil are as follow:—

	inches.	lines.
Extreme length of the body	4	3½
Extreme width of the body	3	3
Extreme height of body (measured on anterior surface)	4	10
Antero-posterior diameter of neural lamina where narrowest	2	9
From mesial line anteriorly to extremity of transverse process	8	
Antero-posterior diameter of transverse process at root	2	9
Between extreme points of anterior oblique processes	3	4
Width of spinal canal (posteriorly)	1	2

The body is much contracted in the centre, so that the sides are deeply concave lengthwise, but convex vertically; they converge towards each other below, thus a vertical section presents a wedge-shaped outline with convex sides. The neuropomal sutures are obliterated, but the share contributed to the body by the expanded bases of the neural laminæ is equal to that indicated by the detached neural arch in Mr. Saull's collection. The neural lamina (*l*) is coextensive with the supporting centrum, but it contracts slightly as it ascends, and so that the posterior notch is still the deepest. The spinal platform is also excavated in front for the reception of the posterior oblique processes; the base of the spine (*c*) increases in thickness as it passes backwards and rises on the thick hinder portion of the platform. The anterior articular facets (*f*) are oval, look towards each other, and their inferior margins meet nearly at right angles, separated only by a slight notch, and further back by the thin anterior edge of the spine. The strong trihedral transverse processes pass outwards and upwards with an inclination backwards from the sides of the spinal platform, and are as it were twisted on their axes, so that the upper surface slopes forwards and downwards internally, but backwards and downwards externally; both edges are thin; below it is supported by a more strongly developed diagonal buttress-like ridge, passing outwards beneath, and gradually subsiding into the transverse process, giving it an increased thickness. This ridge separates two fossæ on the free aspect of the neuropome; the anterior is more or less obliterated by a rough excrescence, which articulates with the head of the rib (*l*); the posterior is remarkably deep, partly roofed over by the base of the plagiapophysis, and separated from that of the opposite side

by the pinched up lower edge of the coalesced peduncles of the met-arthrapophyses, which are unfortunately detached. The spinal canal is nearly circular, and expands slightly in front, where it assumes a transversely oval outline.

In a corresponding anterior dorsal vertebra, No. 2160 of the Mantellian Collection, Plate XXVIII. fig. 7, belonging to a younger and smaller individual, the posterior articular processes are present (*g*), and the perapophysial surface (*l*) is well-defined, but has in the Report on British Reptiles been regarded as the base of the transverse process, whilst the true origin (*d*) of that process is stated to be 'the rough external free border' of the spinal platform, 'probably fractured.' A comparison of figs. 7 and 8 will remove any doubt as to the accuracy of the interpretation here adopted. The wedge-shaped form of the centrum in the above-mentioned vertebræ cannot be regarded of higher value than as indicating their anterior position in the dorsal series; in the Crocodile, the compression of the centrum and the development of an inferior carina ceases in the fifth dorsal, in which also the head of the rib is attached to a facet on the transverse process a little external to its base, while the tubercle is fixed to its extremity, as is the case in the vertebra, Plate XXIX. fig. 9; which from its close resemblance to those just described we have ventured to assign to the Iguanodon, notwithstanding those slight modifications which have induced Professor Owen to regard similar ones as belonging to the genus Cetiosaurus, but which we believe to be simply indicative of position in the same vertebral column, as we have wholly failed in detecting any such differential characters, after repeated examination, as would warrant us in considering this vertebra as specifically, and still less generically, distinct.

This vertebra (Plate XXIX. fig. 9) differs from those above described in the relative shortness and in the cylindrical form of the body, which is much constricted in the centre, so that the surfaces are deeply concave parallel to the axis, but convex in the opposite direction. Its length is 3 inches 6 lines; the width of its anterior subcircular articular facet is 6 inches 1 line, inclusive of the thick rough everted edge, and its height 5 inches 4 lines. The posterior surface is transversely oval; both surfaces are somewhat concave, but the hinder more distinctly so, especially in its upper half, whilst the corresponding part of the anterior aspect is raised into a faint mesial convexity; the adjacent surfaces of contiguous vertebræ are thus coadapted. The spinal canal is 1 inch 1 line transversely where narrowest, but enlarges anteriorly. The neuropomal sutures are obliterated, but the direction of the superficial striæ or rugosities indicate the great expansion of the bases of the neural laminæ, which leave only a narrow tract widening behind the centrum to form the floor of the spinal canal. The neuropome rises from its base nearer the anterior than the posterior surface, and thus the intervertebral foramen is chiefly constituted by the posterior notch. Where most contracted the neural lamina measures 2 inches 6 lines in antero-posterior extent, at its base it is 2 inches 10 lines; seven lines of the body are left exposed behind, and about three in front. But who will venture to base generic distinctions on such trivial characters as these? The enormous spine rises from nearly the whole

length of the platform, which presents a median notch in front, separating the projecting anterior oblique processes, whose oval facets are almost horizontal, being inclined to each other only at a very obtuse angle. The strong transverse processes project outwards, with a slight inclination upwards from its lateral edges, their upper surfaces sweeping gently upwards to the lateral aspects of the spine. The antero-inferior edge of the plagiapophysis is thick, and about 2 inches external to its base bears the rough facet for the head of the rib (*l*), beyond which this process contracts suddenly in antero-posterior extent to lodge the neck of the rib; its extremity is however lost. The thickness of the transverse process diminishes to its posterior edge, and below the diagonal buttress already mentioned in the preceding descriptions, supports it, and is prolonged outwards on the slender portion of the process. The posterior deep fossa behind the buttress exists also, but the anterior is obliterated, the outer surface of the neural lamina being only slightly convex from before backwards, and subconcave vertically.

The spine ascends obliquely backwards and is of nearly equal width throughout; in its basal half it diminishes rapidly in thickness towards its anterior thin margin, which is prolonged forwards to the edge of the platform; in its upper moiety it contracts slightly behind; the posterior border presents a deep groove, obliterated in the upper third by a rough ridge rising from its floor; the apex is broadly truncated and the hinder angle removed; the anterior border is carinate below, but above exhibits a well-marked excavation, becoming wider and deeper above. The greatest diameter of the transverse process at its root is 2 inches 9 lines; between the articular surfaces of opposite sides, for the head of the rib, it measures 8 inches 5 lines. The length of the spine anteriorly is 12 inches 5 lines, its greatest antero-posterior diameter is 3 inches 4 lines, and its greatest thickness 2 inches 3 lines. The greatest width of the centrum is equal to 4 inches 5 lines. The extreme height of this vertebra is 1 foot 8 inches.

Undoubted lumbars of the Iguanodon have not hitherto, so far as I am aware, been recognized, although some of the vertebræ preserved in the Maidstone specimen may belong to that region of the spine. The presence of an articular facet on the transverse process for the attachment of the rib is the distinctive character between the posterior dorsal and lumbar vertebra; unfortunately these processes being readily detached are usually absent. However, we may expect certain modifications in the neural arch of, and also a more robust, perhaps, shorter body in, the vertebræ of the lumbar region. As in Crocodiles, the transverse processes would continue to spring at the level of the spinal platform, but the absence of the rib would cause a further simplification in the sculpturing of the neural lamina, and thus the supporting diagonal buttress of the transverse process would wholly disappear. The neural laminæ themselves would have a less antero-posterior extent than in the more anterior element of the column, and hence the *notches* and uncovered tracts of the body would be more marked than in the dorsal vertebræ, where great strength and size are required in the arch to support the huge ribs of this herbivorous, and it may be, *ruminating*

Saurian. Moreover, the nerves escaping through the intervertebral foramina of this region are larger than those of the dorsal segment of the spine, as they contribute to the formation of the lumbar and sacral plexuses; the vertebral foramen would probably also be wider, since the spinal chord enlarges in that region to form the posterior expansion or ganglion of the *sinus rhomboidalis*, which extends through the anterior half of the canal of the sacrum: the expanded bases of the neural laminæ would therefore leave a portion of the centrum uncovered mesially, to form the floor of the canal and support directly the medulla spinalis.

I can perceive no difference between the posterior dorsal or lumbar vertebræ (No. 2133, 2115)* assigned by Professor Owen to the *Cetiosaurus brevis*, and that last described as corresponding in some respects to the fifth dorsal in the spinal column of the Crocodile, than a diminution in the relief of the buttress supporting the transverse process. In No. 2115 the neural arch is broken away, and the tract of the centrum left uncovered behind to form the floor of the intervertebral foramen, is of greater extent than in No. 2133, indicating a more posterior situation in the vertebral series. The approach to the quadrangular form of the body of this vertebra is no proof whatever of a specific and still less of a generic distinction; otherwise the first sacral vertebra, which is more decidedly quadrate, if found separate, would be equally entitled to a generic value; but its association, in the sacrum from Mr. Saull's collection (Plate XXVI.), with other vertebral bodies of a very dissimilar character, and with the ilium of the Iguanodon, prevents our falling into an error of such magnitude. We may therefore reasonably conclude, that these vertebræ, to wit, Nos. 2133, 2155, belong to the Iguanodon, and that the latter, in the form of the body, approached the first sacral, and was one of the proper lumbar series. The vertebra, No. 2109, attributed in the above-mentioned report to the (so-called) second species of Cetiosaurus found in the Wealden formation (*C. brachyurus*), is also a posterior dorsal or lumbar vertebra of the Iguanodon; the neural arch is much mutilated. The only other element of the skeleton of that species is a caudal vertebra, No. 2161, which also belongs to the Iguanodon; being in fact one of the most anterior of the caudal series, and contrary to the character of the genus to which it was referred, it presents one of the most interesting and instructive examples of the rough surface on the sides of the upper aspect of the centrum, left by the removal of the unanchylosed neural arch. The so-called *Cetiosaurus brevis* being thus founded only on two vertebræ which belong to the Iguanodon, must be expunged from the list of extinct reptiles.

The angular posterior caudal vertebræ referred in the Report on British Reptiles, to the *Cetiosaurus brevis*, I am also inclined to assign to the Iguanodon for the following reasons:—1st, a similar vertebra, as far as can be ascertained, exists in the Maidstone specimen, and in this case an admixture of bones of distinct animals cannot even be suspected; 2ndly, the numerical ratio of the vertebræ of this kind

* Mantellian Collection in the British Museum.

occurring in the Wealden, to those from the same deposits and localities belonging to other regions of the spinal column, all referable to the Iguanodon, excepting the few megalosaurian and crocodilian vertebræ, is such as long ago to have induced Dr. MANTELL to regard them as characteristic of that Saurian; and the occurrence of such vertebræ with those of the sacrum and other bones of the Iguanodon in Western Sussex, described by CUVIER, has already been commented on* :—3rdly, as I shall presently show that the four large anterior caudal vertebræ in the Mantellian Collection, also assigned by the author of the Report to the *Cetiosaurus brevis*, cannot be transmuted into the vertebræ in question by any changes occurring in a consecutive series, there is left for that animal only some terminal caudal vertebræ; while to complete the tail of the Iguanodon just those are wanting; 4thly, but independently of the evidence furnished by the Maidstone specimen, we have seen examples which point out the series of changes by which these angular vertebræ are produced from those of the middle caudal region. These changes, again, are not greater than those that take place in the tail of the Hylæosaurus† and other extinct reptiles, as well as in that of many mammalia.

Let us look for a moment at the vertebræ of the tail of the Mosasaurus as contrasted with those of other regions of the spinal column in that reptile, and we shall then be prepared to admit far greater modifications than are here assumed. Could we *à priori* correctly restore the vertebral column of any animal from scattered fragments, belonging to different individuals, without making allowance for the changes occurring in the series of segments composing that column?

In the form of the terminal caudal vertebræ we may expect to find a very great similarity even in remote genera, and hence it is unsafe to base a generic character on their peculiarities. The genus Cetiosaurus (restricted to the species *medius* and *longus* from the oolite) is founded chiefly on such trivial distinctions, and we may refer to it any caudal vertebra of considerable dimensions with plano-concave or biconcave facets not referable to other known and perfectly determined genera, such as the Ichthyosaurus and Plesiosaurus, of which we have fortunately nearly perfect skeletons, and hence cannot be led astray in the labyrinth of fragments from which we are compelled, in most instances, to construct the lost denizens of the former lands and seas of our globe.

In the caudal vertebræ of the Iguanodon, the body is wedge-shaped; the sides, which are faintly concave lengthwise and flat, or but slightly convex vertically, converge towards each other below; in the three or four most anterior, they present a concavity beneath the base of the short caudal rib, which is wedged between the centrum and the root of the neural lamina; in a very instructive example in Dr. MANTELL's Collection, the pleural element has dropped out from one side, leaving a deep cavity now filled by matrix‡. The caudal ribs disappear towards the middle of the tail, after which the bodies of the vertebræ have a subhexagonal form, Plate XXX. figs. 12, 13;

* *Ante*, p. 277. † See Plate XXXII. ‡ Philosophical Transactions, 1841, Plate VIII. fig. 37 *e*.

the angles of the upper or basal surface of the centrum, which support the impacted roots of the ribs, are therefore removed, and replaced by planes converging towards each other above, and forming with the primary surfaces a longitudinal ridge on each side, which descends gradually to its centre in the terminal vertebræ, at the same time becoming more prominent as the body assumes a more hexagonal figure. In the vertebræ immediately adjoining the sacrum, the anterior articular surface is flat or slightly concave in its lower moiety, but convex above, whilst behind the reverse is the case, and thus the vertebral surfaces are coadapted; in the middle caudal elements, the body has plano-concave facets; the anterior then becoming depressed in the terminal vertebræ, which are thus biconcave. The expanded bases of the neural laminæ leave a portion of the centrum uncovered mesially, above they contract and leave considerable tracts of the body exposed; the posterior notch is twice the depth of the anterior. The elongated space ascends obliquely backwards, increasing in width, but is abruptly truncated; the hinder border is in its upper half, while from the lower moiety of the anterior margin a thin plate extends forwards, its base reaching to the deep notch which separates the pro-arthrapophyses; these receive between them the closely approximated corresponding posterior processes which look outwards, and are developed on the hinder part of the base of the spine, their thin posterior edge being separated by a shallow notch. The free aspect of the neuropome is flat in the axis of the vertebra, but concave in the opposite diameter, the concavity passing upwards into the lateral surface of the spine.

The spinal canal is circular, widening slightly at each extremity. The chevron bone is not developed at the two first caudal intervertebral spaces in the fossil, Plate XXX. fig. 17, *x*, which represents four vertebræ belonging to the same individual as the fragments of the sacrum, figs. 15 and 16: there is a marked increase in the size of the body to the third, and then it diminishes; that of probably the second caudal is but little contracted inferiorly, whilst in the third it is carinate, and encroached on posteriorly by the semicircular surface descending obliquely forwards, and giving attachment to the anterior facet of the expanded base of the chevron bone, which is wedged into the intervertebral space, truncating the opposed angles of the contiguous vertebræ. The laminæ of the chevron bone (*angiopoma*) coalesce at their distal extremity, and develope a long inferior spine (*angiacantha*); they also meet above the hæmal canal to form the expanded wedge-like base, the anterior facet of which is the largest. The angioponal impressions are never in pairs, but always united into a single subtriangular rough irregular surface, the posterior of which is most extensive; the narrow tract separating them is deeply concave lengthwise, carinated in the more anterior caudal vertebræ, but deeply sulcated in the more posterior elements. The chevron bones are continued further back than the ribs, and the angiopomal impressions are present on many of the hexagonal terminal vertebræ; the posterior are the largest and partly subdivided by a slight median ridge. The dimensions of the first caudal of the above series are subjoined.

	inches.	lines.
Height of anterior surface of body	3	6
Width of anterior surface of body	3	7
Length of the body (inferiorly)	2	1
Width of spinal canal in centre		5½

In the Crocodile the chevron bone commences at the second caudal and terminates at the twentieth, but the rib ceases at the fifteenth, the number of vertebræ composing the tail being forty-two.

The four huge caudal vertebræ already mentioned as assigned to the *Cetiosaurus brevis**, exhibit very peculiar characters, fully detailed by Professor Owen, and are especially distinguished by the absence of projecting posterior articular processes; 'the posterior articular surfaces being impressed upon the sides of the posterior part of the base of the spine,' while the anterior oblique processes 'reach beyond the middle of the vertebra next in front, and pinch, as it were, the back part of the base of the spine so as to impress upon it the surfaces representing the posterior articular processes.' If then these anterior caudal vertebræ are characterized by the absence of the posterior oblique processes, and as in the succeeding elements of the series the invariable tendency is to the disappearance of articular processes whether in front or behind, the terminal angular vertebræ (Plate XXX. figs. 12, 13) in which the posterior oblique processes are still well-developed, projecting from the back part of the base of the spine, cannot belong to the same species as those just described, without violating those analogies which have hitherto held good; for we cannot well admit the reappearance of posterior oblique processes, after they have once subsided, in a more posterior part of the same caudal series. Other discrepancies equally marked forbid their association.

There remain then to represent the *Cetiosaurus brevis*, in the specimens under consideration, only the above four caudal vertebræ, which are truly so whale-like in their form, as to be pre-eminently worthy of that generic appellation. Probably they are portions of one or other of the species of that genus from the Oolites, indicated by Professor Owen, chiefly from the more posterior caudal vertebræ.

The close resemblance which these unique caudal vertebræ† present to two remarkable ones figured by Cuvier‡ from the oolite of Honfleur, was long ago recognized by Dr. Mantell. They are thus described: 'à corps cylindrique, presque aussi long que large, marqué de chaque côté d'une petite fossette, à faces planes, circulaires, à canal médullaire fort étroit, à partie annulaire non articulée; l'apophyse épineuse haute, et droite; les transverses au niveau du canal médullaire, grosses cylindriques, dilatées verticalement au bout; et, ce qui est très remarquable, *les*

* *Ante*, p. 294.

† An outline of one of these vertebræ is given in Dr. Mantell's Memoir, Philosophical Transactions, 1841, Plate IX. fig. 13.

‡ Tome v. pl. 22, figs. 1 and 2. Oss. Foss. ed. 1824.

articulaires postérieures petites, pointues, rapprochées, et donnant dans deux petites fossettes entre les antérieures et au-devant de la basse de l'épineuse.' 'Elles doivent appartenir à une espèce de Sauriens très-voisine des Plésiosaurus.' Ocular inspection can alone safely indicate the propriety of associating these vertebræ together as belonging to the same species or genus. Probably the mutilated remains of a large Saurian, from the lower greensand at Hythe, may belong to this genus, and also the teeth of the provisional '*Polyptychodon*' occurring in the same formation. The Wealden deposits intercalated between two marine formations, contemporaneous with them in a certain sense, may well contain a few vertebræ of the great Saurians which swarmed along the shores of the bays indenting the "Country of the Iguanodon," or even entered occasionally the mouths of its mighty rivers. If these four caudal vertebræ are specifically different from any found in the more ancient oolite, to prevent confusion, and to remove the objection that may well be raised against the *nomen triviale* '*brevis*'—for who will venture to indicate the relative length of an animal with no known affine, from four of its anterior caudal vertebræ?—we propose to name the species to which they belong, *Cetiosaurus Conybeari*, in honour of the Dean of Llandaff, one of the earliest, ablest, and most distinguished geologists and palæontologists of England.

The massive sacrum of the Iguanodon (Plate XXVI.) is composed of a series of six vertebræ anchylosed together in a nearly straight line; the neural arches unite at an early period above the intervertebral foramina, and form a tunnel over the spinal canal, while the short spinous processes coalesce into a thick median ridge. The bodies of the second, third, and fourth vertebræ, are only half as broad as those of the first and two last, which are of nearly equal width, but all have the same length. The free articular surface (a') of the first sacral is flat or rather slightly convex, especially in the vertical diameter, and presents an oval contour; the posterior facet of the sixth (a'') is subcircular and slightly concave, but deepest above.

The body of each is more or less constricted in the centre, so that their surfaces are deeply concave lengthwise; this contraction, and the marked expansion towards the articular facets, is most striking in the smaller middle vertebræ, least so in the first; and the more or less rounded transverse ridges at the lines of anchylosis give the inferior surface of this chain an undulating outline. The neural lamina of the first sacral about its root is much contracted in the antero-posterior diameter, and chiefly from behind forwards, so as to leave a large tract of the body exposed posteriorly, while the anterior notch is comparatively shallow. The neural laminæ of the four succeeding vertebræ are displaced slightly forwards, so that the anterior extremities of their bases rest upon and excavate the postero-superior angles of the body in front, and are also, perhaps, partly wedged into the intervertebral space; each however impresses and is mainly attached to its own centrum; and that of the last sacral is restored almost to its normal position, projecting only slightly beyond the anterior aspect of the body, leaving a portion of its upper surface uncovered behind, to form

the floor of the large intervertebral foramen. The preceding foramina intervertebralia, instead therefore of being situated more or less over the union of two contiguous bodies, are thrown forwards in the same ratio as the neural laminæ, encroach on the centrum in front, and generally occur over the junction of its posterior and two anterior thirds. In the first sacral the body has a subquadrangular section; the lateral aspects are impressed by a fossa beneath the root of the neuropome, and meet the inferior surface nearly at right angles, which are rounded off; the lower aspect is but slightly convex transversely; sometimes it presents a median ridge separating two very shallow concavities, perforated by vascular foramina. The anterior oblique processes project considerably beyond the margin of the neural arch, and are nearly horizontal, and separated from each other by a wide notch. The bodies of the three succeeding vertebræ, as already mentioned, are narrow, constricted in the centre, compressed laterally in the lower moiety, and rounded transversely below, with a more or less distinct longitudinal mesial ridge, sometimes replaced by a groove in the third. In other cases they appear to be flattened inferiorly, without our being able to regard them as distinct, so that there appears to be a considerable range of variation attributable to age and sex, &c. Each lateral surface presents a small digital fossa (Plate XXX. fig. 16) towards the middle of its height and nearer its posterior extremity, as if the centrum had been pinched up between the thumb and fore-finger. Above the fossa the centrum expands, the anterior angle (Plate XXX. fig. 14*) of the expanded portion being, as it were, removed and flattened out by the base of the neural lamina, and also, perhaps chiefly, by the sacral rib, which is wedged deeply into the intervertebral space; the posterior angle (Plate XXX. fig. 14§), like that of the first sacral, is removed, but to a much less extent than the anterior; between them is the smooth, semilunar, oblique notch (Plate XXX. figs. 14, 15, 16, ¤), impressing the slightly elevated parapet which bounds externally the wide, deeply concave floor of the spinal canal. In the two posterior sacral vertebræ the bases of the neural laminæ begin to expand inwards, so as to cover the upper surface of the centrum, in the last sacral meeting in the centre and leaving only a small triangular tract in front and behind exposed; thus the calibre of the canal is diminished. The bodies of the two last vertebræ expand to nearly the same diameter as the first, but the lateral surfaces converge more or less rapidly to an inferior mesial convexity, varying in breadth and prominence. By the relative size of the two extremities of the spinal canal in the sacrum, we are enabled most readily and certainly to determine its position. The bases of the strong sacral ribs (Plate XXVI. *h*, *h*, *h*, Plate XXX. figs. 15, 16 *h*) are compressed in the antero-posterior diameter and impacted in the intervertebral spaces, descending nearly to the inferior surface of the centre, and rising high upon the neural laminæ, which are also excavated to give an additional surface of attachment. The neural laminæ also send out vertical processes (*plagiapophyses*) which are superimposed upon the sacral ribs, and early coalesce with them to form the thick partitions, which extend outwards, gradually increasing in length to the last; and

enclose between them the large circular sacral foramina. The inferior angles of the free extremities of the five posterior ribs expand and coalesce to form a band completing the sacral foramina without (Plate XXVI. h''). The thickest and strongest of these septa is the second, it is also inclined slightly backwards; the second or third posterior ones have a tendency forwards. The corresponding compressed rib-like process of the first sacral is perhaps chiefly formed by the transverse process, and does not appear to have reached the band above-mentioned. The vertical septa extended as high as the base of the spinal ridge, and appear to have had a convex upper edge and a concave lower one. Curious bony buttresses (Plate XXVI. 3*) of a triangular form seem to have partly roofed over some of the sacral foramina; these are most probably remains of a lateral expansion of the side of the spinal platform, at right angle hence to the vertical portion of the transverse process. These parts are, however, so much mutilated that we must have more perfect specimens for examination ere many interesting points can be fully elucidated. The band above-mentioned is curved longitudinally in its anterior two-thirds, with a concavity looking downwards and outwards, the posterior part of the arc being twisted slightly from within outwards on its axis; the portion contributed by the two posterior ribs is convex externally, passing into the concavity at a very obtuse angle. The bands of opposite sides are much more closely approximated in front than behind, but are most remote opposite the angle just mentioned.

This instructive specimen of the sacrum also points out the true position of the *Ilium* (Plate XXVI. A), the form of which is well seen in the two detached examples in the Maidstone Iguanodon*. The slender anteriorly prolonged extremity, which is supposed in the Report on British Reptiles to be the posterior, is only an exaggerated condition of the short spine projecting forwards from the ilium in the smaller Lacertæ. From the form and position of the head of the femur, I am inclined to think that no part of the surface of the acetabulum is present in this mutilated specimen; it is perhaps fractured (A''') across the neck or contracted portion, beneath which it would expand to contribute to the formation of the acetabular fossa.

The beautiful and interesting fragment of the sacrum of a Dinosaur, consisting of the four posterior vertebral bodies anchylosed together, Plate XXVII. figs. 2, 3, presents certain differences in the form of the centrum, which are perhaps due to age and sex; but I am inclined with Dr. Mantell to regard it as probably belonging to the Hylæosaurus, which must have presented a nearly similar structure of the pelvis. The sacral fragment referred to the Hylæosaurus by Professor Owen, cannot at present be found to institute the necessary comparison with the present specimen. The age and size of the individual appear to have had no very obvious relation to the occurrence of anchylosis in the sacral column, as we meet with examples of very dissimilar size both anchylosed and separate. There is the same disproportion between the central and extreme elements of this chain as we have seen in the sacrum

* Philosophical Transactions, 1848, Plate VIII. fig. 28.

of the Iguanodon, but the bodies are relatively broader and flatter, and not so much pinched up beneath the intervertebral notches; but a reference to the Plate will furnish a better idea of these differences than can be conveyed in words.

Since the observations on which the above remarks are chiefly founded were made, Dr. Mantell has informed me, that according to the account given by the fisherman who collected the cervical, anterior and middle dorsal, first sacral, and anterior caudal vertebræ—all of which I had assigned to the Iguanodon—they were found not only in the same limited area, but in such collocation as to give rise to the conviction in the mind of one who had certainly no theory to support, that they constituted portions of the same 'backbone,' and were associated with bones of the hinder extremity of the Iguanodon of proportionate size, now in Dr. Mantell's Collection, and partly described in this memoir. Although unwilling to lay any undue stress on this circumstance, it will, we conceive, raise in the minds of future observers such presumptive evidence in favour of the opinions here advanced, as may, independently of the mere intrinsic value of the argument from analogy, lead them to view favourably our proposed restoration of the vertebral column of the Iguanodon.

The time is perhaps not far distant, when the exertions of the many collectors of the Wealden fossils will yield the materials for continuing these interesting researches, and modifying or confirming our conclusions. And, although, we feel it is difficult to convey to the minds of others that conviction of their accordance with nature, which has been impressed on our own after the repeated examination of a more extensive and instructive series of specimens than has, perhaps, fallen under the observation of any other palæontologists, we may be permitted meanwhile to indulge the hope that a step has been taken in the right direction, to reconstruct the skeleton of the marvellous Reptilian Herbivore, whose earliest known remains were first exhumed from the Wealden formation of Sussex, during the infancy of Palæontology.

Description of the Plates.

PLATE XXVI.

Sacrum of the Iguanodon; in the Collection of W. D. Saull, *Esq., F.G.S.*
(One-half linear, the natural size.)

Figs. 1, 2, 3, 4, 5, 6. The six anchylosed vertebræ composing the Sacrum; 1, is the first or most anterior vertebra.

a'. Anterior articulating facet.

a''. Posterior ————————.

h. Sacral ribs.

h'. Confluence of the sacral ribs at the outer extremity of the left side.

h''. Sacral foramina.

* Expansion of bone from the rib across a sacral foramen.

A. The right ilium.
A′. Anterior prolongation of the same.
A″. Posterior extremity of the ilium, of which several inches are wanting.
A‴. Crest or upper margin of the same.
A⁗. Remains of the neck of the ilium.

PLATE XXVII.

This fossil consists of the four distal anchylosed vertebræ of a sacrum belonging either to the Hylæosaurus or Iguanodon (*natural size*). Collected by Captain Lambart Brickenden, F.G.S.

Fig. 2. The inferior or visceral aspect.
Fig. 3. The side or lateral aspect.
3, 4. The two middle slender vertebræ.
5, 6. The two larger and posterior vertebræ.
h. Sacral ribs.
j. The spinal canal.
k. Line of intervertebral anchylosis.
b. Bases of the neural laminæ.

PLATE XXVIII.

Vertebræ of the Iguanodon.

Fig. 4. Cervical vertebra from Brook Bay: this specimen is somewhat compressed vertically, so as to appear wider and more elliptical transversely than natural.
4^a. Inferior view.
4^b. Upper view.
4^c. Lateral view.

The several parts in this and the other vertebræ are indicated by the following signs:—

a. The body or centrum.
a′. The anterior articulating surface of the same.
a″. The posterior ————————————.
b. The neural arch.
c. The spinous process.
d. Superior transverse process.
e. Inferior transverse process.
f. Anterior oblique process.
g. Posterior oblique process.
h. Rib or costal process.

i. Chevron bone.
j. Spinal canal.
k. Line of intervertebral anchylosis.
l. Articulating surface for the head of the rib.

Fig. 5. Anterior dorsal vertebra from the Isle of Wight.
5*. Anterior view.
5^b. Posterior aspect.
5^c. Lateral view.

Fig. 6. Cervical vertebra, in Mr. SAULL's Collection, lateral view: the anterior convexity has been chiseled away.

Fig. 7. Middle dorsal vertebra, in British Museum.
7*. Lateral view.
7^b. Anterior view.

PLATE XXIX.

Dorsal Vertebræ of the Iguanodon.

(one-fourth linear, natural size.)

Fig. 8. Middle dorsal vertebra. Isle of Wight; found with fig. 4, Plate III.
8*. Posterior aspect.
8^b. Anterior aspect.
8^c. Lateral view.

Fig. 9. Posterior dorsal vertebra found with the above.

Cervical Vertebræ of a very young Iguanodon.

(natural size.)

Fig. 9*. A series of three convexo-concave vertebræ from the Wealden of the Isle of Wight.
9**. The upper or dorsal aspect, showing the spinous and oblique processes of the neural arches; the vertebræ are somewhat displaced, and injured by compression.
9^b*. Lateral view of the same.
9^c*. Lateral view of one of the vertebræ detached.

This interesting series of cervicals (for the loan of which I am indebted to J. S. BOWERBANK, Esq.) was associated with other portions of the skeleton of a very young individual, consisting of a connected suite of fourteen dorsal vertebræ of the usual type, several ribs with portions of the dermal integument, metatarsal, phalangeal, and ungueal bones, and several others which are at present too much concealed by the investing sandstone to admit of their identification.

These vertebræ are especially instructive, because they establish the true characters of the cervical region of the spine of the Iguanodon in a very young state.

Unfortunately the bodies of the vertebræ have been crushed and compressed almost flat laterally, and the natural form of the inferior part of the centrum is destroyed, the visceral aspect presenting a sharp ridge, and thus assuming a different contour to that of the adult cervical figured in Plate XXVIII. fig. 1, which has been compressed in an opposite direction. Nevertheless, the close analogy between these vertebræ is sufficiently obvious; the structure of the neural arch (as seen in fig. 9**) is identical; and the only essential difference in the bodies of the respective vertebræ, is that the anterior articulating facet (a') is much less prominent in the young specimen than in the adult: but as the posterior facet (a'') is deeply concave, it is probable that in the recent state the anterior facet possessed a cartilaginous convex epiphysis, by which the ball-and-socket joint was completed: as in the skeleton of the young *Gavial* the facets of the sacro-coccygeal vertebra are flat, though very convex in the adult*; so in the Iguanodon, the ball and socket of the cervicals may not have been fully developed and ossified till the reptile arrived at maturity.

Fig. A. A *concavo-convex* dorsal vertebra from Tilgate Forest: natural size.

I have introduced this figure to prove the existence in the Country of the Iguanodon, of small Lizards having the spinal column constructed of vertebræ anteriorly concave, and posteriorly convex, as in the living Iguanas, Crocodiles, &c.: the very reverse of those above referred to the Iguanodon.

A, is a lateral view; and A′ the anterior aspect, showing the deep socket for the reception of the head of the antecedent vertebra.

PLATE XXX.

Fig. 10. The right *Scapula* or Omoplate of the Iguanodon: from Tilgate Forest (one-fourth natural size).

10^a. Inner aspect.

10^b. The external aspect.

a. The upper or spinal end.

b. The humeral extremity.

c. The coracoid facet or articulating surface.

d. The glenoid facet, forming half the cavity for the reception of the head of the humerus.

Fig. 11. The right *Coracoid* of the Iguanodon; drawn of a size to correspond with the scapula.

s. Scapular facet or surface to articulate with the scapula.

d'. Glenoid facet, forming with the corresponding part of the scapula, the glenoid socket.

e. Notch for the passage of vessels.

* See Wonders of Geology, 6th edit. p. 418.

Fig. 12. Posterior caudal vertebra of the Iguanodon.
12*. Anterior aspect.
12*. Lateral view.
Fig. 13. Distal caudal vertebræ of the same; one-half natural size. This specimen and the preceding are from Tilgate Forest.
Fig. 14. A middle sacral vertebra of the Iguanodon from Brook Bay; one-half natural size. In the collection of J. Baber, Esq., of Knightsbridge.
14*. Lateral view.
14*. Upper or spinal aspect.
Figs. 15, 16, 17. Represent portions of a chain of sacral and caudal vertebræ of the same Iguanodon: from Charlwood in Surrey. In the cabinet of P. Martin, Jun., Esq., of Reigate.
Fig. 15. The two anterior sacrals; z, foramen for the transit of the sacral nerves.
Fig. 16. An entire middle sacral, with portions of the adjoining vertebræ anchylosed at each end.
Fig. 17. Four consecutive anterior caudals with remains of the chevron bones (*i*).

PLATE XXXI.

Humeri or Arm-bones of the Iguanodon.

Fig. 18. Inferior portion of the right *Humerus* of a young Iguanodon; one-third natural size.
18*. Front or anterior view.
18*. Lateral view.
18*. Posterior view.
18*. The condyloid articulating surface seen from below.
Fig. 19. Right Humerus, one-twelfth natural size: from the Isle of Wight; in the possession of Mr. Fowlstone of Ryde.
19*. Posterior view.
19*. Front or anterior aspect.
19*. Articulating surface of the proximal extremity of the bone seen from above.
19*. Distal or condyloid articulating surface seen from below.
Fig. 20. Right Humerus of the Iguanodon, from the Maidstone specimen in the British Museum; one-sixth natural size: the posterior aspect only is exposed.
Fig. 21. Upper extremity of the Humerus of a very young Iguanodon: from Tilgate Forest; one-third natural size.
21*. Posterior aspect.
21*. Anterior view.
21*. Articulating surface of the proximal extremity seen from above.

The principal points in the above specimens are indicated by the following letters.

a. The head.
b. Inner tuberosity.
c. Outer tuberosity.
d. Deltoid crest, or ridge for the insertion of the deltoid muscle.
e. Inner condyle.
f. Outer condyle.
g. Olecranal furrow or depression.

PLATE XXXII.

Vertebræ and Dermal Bones of the Hylæosaurus.

Fig. 22. Posterior portion of the spinal column of the Hylæosaurus, from the Weald of Sussex; one-sixth natural size.

The *series of nine vertebræ* anterior to the three terminal ones in this specimen, lies imbedded on the stone in a position the reverse of that of the other portions of the spinal column; the hæmal aspect of the bodies of the vertebræ, with the corresponding chevron bones (*i*, *i*, *i*), being uppermost.

22^a. Outline of the form and arrangement of the chevron bones in the distal part of the column.

22^b, 22^c, 22^d. Illustrate the modifications of form in the chevron bones in the anterior part of the specimen.

22^c. Distal chevron bone.

22^f. Middle ————————.

22^g. Anterior ————————.

Fig. 23. Dermal bone from the middle portion of fig. 22; one-half natural size.

Fig. 24. Dermal tubercle or horn of the Iguanodon; natural size: from Ridgway, near Weymouth.

XVI. *On the Reduction of the Thermometrical Observations made at the Apartments of the Royal Society, from the years 1774 to 1781, and from the years 1787 to 1843.*

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Communicated by John Lee, *Esq., LL.D., F.R.S. &c.*

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THE meteorological observations which have been made at the Apartments of this Society, extend over so long a period of time, that if the instruments used have been good, and the observations have been faithfully recorded, the results which can be deduced from them must be of great value; on the other hand, if either of these essentials has been neglected, any results from them would be valueless.

To the present time, so much uncertainty seems to have rested upon these observations, and so much suspicion upon their accuracy, that they have been little used, and generally when reference has been made to them, it has been accompanied with the remark that the results were not satisfactory, and till recently such was the opinion which I entertained myself.

In the year 1848 I had the honour of presenting to this Society the determination of the diurnal variations of the different meteorological elements, and the corrections to be applied to monthly mean values of observations taken at any time of the day, to deduce from them the true values for the month.

The accordance which I had found in the diurnal variations year by year, led me to suspect that the corrections would apply to a great number of years. To determine this I had recourse to the observations of this Society. Throughout this series two thermometers have been used in the ordinary daily observations; each was placed 2 or 3 inches from a wall, one facing E.N.E. and the other W.S.W. As the sun shines on the eastern part of the building in the morning, the thermometer to the westward was made use of for the morning observation during that season of the year when the sun rose high enough to affect the other: for all other observations, that to the eastward was employed. Of these instruments two observations have been taken daily, the one before and the other after noon; the actual times, however, have been different at different epochs, and at times different in the same month; these circumstances were favourable for my purpose, though undoubtedly they have been highly prejudicial to the character of the journal in consequence of the diurnal variations being then unknown, and the mean monthly values as printed differing from the true values for the month by different quantities.

At every variation of the times of observation, and at different epochs with the

same times, I determined two mean values, the one from the morning observations, and the other from the afternoon observations, and compared the difference between them, with the difference as exhibited in my tables; in nearly all cases the values thus found were nearly alike; hence it appeared that the corrections apply equally well to all the years since 1774.

Having ascertained this fact, I felt I had the means, to a certain extent, of determining the quality of the instruments which have been used, as, for the most part, different instruments were used in the morning and in the afternoon observations, and also the correctness of the observations generally; and thus the means of ascertaining the value of the results which could be deduced from them.

I need not mention all the tests to which I have subjected the observations, but briefly state that the results were, a conviction on my mind that the instruments had been uniformly good, that the observations had been faithfully recorded as read from the instruments, and that very great care had been taken in reading at the times stated; the latter circumstance was most satisfactorily proved from the fact of the results being the same when the times of observation have been such that the changes were rapid, and consequently a small error in the time of reading would have entailed a considerable error in the results.

I found however that during the time the maximum and minimum thermometers were in use, their readings were frequently in defect or excess respectively as compared with those of the other thermometers made during the day, and this was found to be more frequently the case in the later than in the earlier observations. On examining farther and bearing in mind that a self-registering thermometer, whose reading is taken once a day only, merely registers the extreme reading which has taken place in the preceding twenty-four hours, many of the apparent discrepancies vanished, yet still some remain for which I cannot account. I know it has been said that at times the sun has shone upon, or its reflected rays have impinged upon the maximum thermometer; but, if this has been the case, I feel certain that it was of rare occurrence, and therefore it is not sufficient alone to warrant us in rejecting a long series of observations: possibly no journal of the weather has been kept for any length of time, where an attempt has been made to have the instruments properly exposed, that such accidents have not happened.

There being thus three independent methods of determining the mean temperature of the air, viz. first, from the morning observations by one thermometer; secondly, from the afternoon observations by another thermometer; and thirdly, from the observations made by the maximum and minimum thermometers, I had every means of ascertaining whether the one or the other of these methods was bad. Having satisfied myself that the observations were well worth any amount of labour bestowed upon them, I became anxious to reduce them to a useful and accessible form; but the amount of work required to reduce observations extending from the year 1774 to 1843, with the exception of five years, from 1781 to 1786, during which interval no observations

were made, was so great, that, unassisted, I hesitated to begin the reductions, although the results, as printed in the Philosophical Transactions, are unfit for application to useful purposes, there having been a departure in the observations themselves, from an absolutely necessary condition, viz. that of taking the observations at stated times, when the diurnal variations were unknown.

About two months after this, William Farr, Esq., who is at the head of the Statistical Department in the office of the Registrar-General, wished me to supply the meteorological particulars of as many years as could be given with certainty, to accompany statistical tables upon which he is engaged. Finding therefore that the demand for the results from trustworthy observations, extending backwards many years, was increasing, with the knowledge that such could be deduced from the observations of this Society, together with the hope of connecting the Greenwich series of observations with these, I readily undertook to perform the work.

I have now the honour of presenting to the Society the results from all the Thermometrical Observations which have been taken at Somerset House. I have chosen these in preference to the Barometrical, as being at present more important, and more immediately useful. The prevalence of epidemic complaints renders it desirable to compare the simultaneous meteorological conditions with those, when no particular disease prevailed. The cholera epidemic now prevalent has caused me to prepare this paper as quickly as possible.

I shall now proceed to explain the manner in which the annexed Tables were formed.

Table I. was made by applying the corrections to the mean of the observations made during every month, according to the times of the day at which they had been taken, and thus determining, from the observations taken during the day, one mean temperature for the month, which has been used as the true mean at all times when the self-registering thermometers have not been used; at times when they were in use a second mean has been found by applying the corrections as mentioned in my paper in the Philosophical Transactions in 1848. Thus two values of the same element have for the most part been found monthly; the difference between these results in most cases was a quantity less than a degree. As both determinations rested upon two observed readings daily, I considered them entitled to equal weight, and in most cases I have taken a simple arithmetical mean between them, which I have adopted as the true mean for the month. From the accordance thus found by these two methods, I inferred that either could be used with safety at times when both sets of instruments were not in use.

TABLE I.—Showing the mean temperature of each month, as deduced from the corrected mean of the two observations of the thermometer daily, and the corrected mean as found from the maximum and minimum self-registering thermometers, made at Somerset House during the years 1774 to 1781, and from 1787 to 1843.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1774.	35°1	39°4	43°9	47°9	52°2	61°0	63°8	61°5	55°8	50°1	40°5	38°5
1775.	42·0	43·3	42·8	50·8	55·2	63·5	64·0	62·1	59·5	49·5	41·5	40·7
1776.	28·6	41·4	44·8	48·3	51·7	59·6	63·8	62·0	55·6	52·8	44·0	41·5
1777.	35·5	37·2	45·7	45·1	53·4	57·2	61·5	63·7	59·2	52·6	45·0	37·2
1778.	36·4	37·0	41·2	48·0	55·9	62·2	68·0	64·8	54·5	47·3	46·0	44·2
1779.	36·4	46·7	48·1	51·8	55·8	58·9	65·9	65·2	61·8	53·2	43·2	41·6
1780.	30·2	36·7	50·3	44·7	57·2	60·0	64·2	67·0	60·4	51·3	40·8	38·0
1781.	37·8	41·7	43·7	47·2	54·2	62·4	66·3	64·3				
1787.	38·3	40·9	43·9	45·5	52·4	58·7	62·4	62·4	55·5	49·9	40·9	41·0
1788.	39·0	40·1	39·7	50·6	57·4	59·5	61·6	61·2	57·0	50·4	41·9	30·4
1789.	35·0	41·3	35·5	45·2	54·3	55·7	59·8	61·5	55·7	48·1	40·0	43·0
1790.	40·2	42·6	44·3	42·0	53·7	57·7	60·1	61·2	55·0	50·8	43·3	40·4
1791.	41·4	40·2	43·2	49·9	50·5	58·5	60·5	62·7	57·9	47·9	42·6	36·2
1792.	36·5	38·8	43·2	50·0	50·7	55·3	59·6	63·5	56·5	50·0	44·5	41·4
1793.	36·9	41·1	40·4	42·5	51·8	56·3	65·9	60·3	53·9	53·2	44·2	42·4
1794.	34·9	46·1	45·4	50·7	51·7	58·5	66·3	60·7	54·8	49·6	44·6	38·2
1795.	35·5	35·5	39·7	46·2	53·0	54·8	59·9	62·1	61·9	54·7	42·0	46·2
1796.	46·9	41·9	40·1	49·4	51·2	57·0	59·6	61·2	60·2	47·8	41·6	31·8
1797.	37·0	37·0	39·0	45·8	52·4	55·7	64·3	60·3	55·7	48·3	42·7	42·6
1798.	39·4	39·3	41·8	50·3	54·7	62·1	62·2	62·8	57·6	51·1	41·3	35·1
1799.	34·9	37·8	38·3	42·6	50·6	56·5	60·8	58·8	55·4	48·6	44·2	34·2
1800.	38·5	35·5	38·6	49·5	55·1	56·0	64·2	65·0	59·0	49·2	43·5	39·6
1801.	41·1	39·9	45·2	46·5	54·7	59·3	61·5	63·8	59·8	52·2	41·5	37·5
1802.	34·5	40·3	42·2	49·6	51·3	58·5	57·5	66·1	58·1	45·8	41·8	39·2
1803.	35·0	37·7	43·4	48·9	51·2	57·1	64·7	63·0	53·5	50·2	43·2	44·7
1804.	44·8	38·3	42·2	44·8	57·7	62·2	61·2	61·2	60·5	52·7	45·4	37·0
1805.	36·1	40·1	43·1	46·4	50·7	55·4	60·1	63·0	60·4	48·7	41·2	40·9
1806.	42·2	42·9	41·8	44·1	56·1	60·7	62·2	62·7	58·1	52·5	48·7	48·2
1807.	38·3	41·4	38·1	46·5	56·1	58·6	64·5	65·0	54·2	54·3	40·0	38·0
1808.	38·6	37·7	38·2	43·6	58·2	58·9	66·7	63·8	56·4	47·4	45·2	37·4
1809.	32·0	45·5	43·7	42·2	56·8	58·4	60·6	60·2	57·2	50·9	40·8	42·4
1810.	36·0	40·0	43·3	47·5	50·8	59·4	61·9	61·8	60·5	53·1	44·1	40·0
1811.	34·2	41·3	44·0	49·0	56·4	58·0	61·0	58·9	58·3	56·3	46·3	39·8
1812.	37·5	43·0	39·5	42·6	52·3	54·9	58·4	58·3	57·0	50·1	41·9	36·5
1813.	36·0	43·0	44·2	44·9	53·4	56·2	59·9	59·6	55·6	48·6	41·5	38·0
1814.	28·5	35·4	36·2	49·2	49·7	54·3	62·1	59·9	56·0	48·6	42·0	42·5
1815.	33·5	42·6	46·1	47·7	55·8	58·9	60·9	61·7	63·4	52·7	40·2	38·4
1816.	38·3	38·0	40·3	44·5	49·9	54·0	55·5	59·2	60·0	52·1	40·6	39·2
1817.	40·8	44·9	42·7	45·0	49·0	60·0	58·7	56·7	56·6	46·3	48·2	38·5
1818.	40·9	37·2	42·0	46·7	53·6	63·8	67·2	64·9	61·8	55·0	50·5	40·2
1819.	41·7	41·4	45·1	49·3	55·3	57·3	62·7	65·1	59·2	48·8	42·1	38·4
1820.	33·3	38·3	42·4	50·4	53·1	57·0	60·5	59·8	55·5	48·3	42·7	41·3
1821.	39·1	37·4	43·9	51·5	50·5	55·0	58·7	63·0	60·7	51·6	48·9	45·7
1822.	41·4	44·7	48·4	47·8	56·9	63·5	63·5	62·6	57·1	53·3	49·5	37·8
1823.	33·4	39·5	40·9	43·9	55·7	56·3	60·1	61·1	56·5	48·9	44·3	41·3
1824.	39·0	37·6	40·6	44·9	50·6	55·9	63·5	61·3	58·8	51·1	47·5	43·2
1825.	40·0	39·5	39·6	49·8	54·7	59·8	66·2	63·1	61·0	52·1	42·5	42·0
1826.	33·6	43·6	44·3	50·1	51·1	63·8	66·6	64·7	57·4	53·7	41·2	43·2
1827.	33·0	33·0	44·2	47·9	53·8	58·5	64·5	60·3	58·0	53·1	42·6	45·5
1828.	41·4	41·6	44·6	47·6	55·4	60·9	62·9	60·3	58·6	51·2	45·6	43·9
1829.	33·3	39·8	40·1	44·8	55·6	59·9	61·1	59·0	54·3	48·8	40·6	36·3
1830.	32·3	35·6	46·9	49·4	55·8	56·2	64·9	59·5	54·6	52·2	45·7	36·3
1831.	36·0	42·6	45·0	49·2	53·9	60·3	65·3	64·6	57·5	56·3	45·6	43·4
1832.	38·9	38·3	41·6	48·3	52·6	60·1	62·2	62·3	57·7	52·5	45·0	43·8
1833.	36·1	43·8	38·7	46·3	60·5	60·7	62·1	58·8	54·6	49·6	44·8	46·0
1834.	46·0	41·6	45·1	46·1	53·0	62·0	65·1	63·6	59·4	51·8	45·4	42·4
1835.	39·6	42·6	42·1	47·5	54·0	60·9	65·4	64·6	58·2	49·3	44·3	36·3
1836.	38·8	38·3	44·8	44·4	53·9	59·9	63·9	60·2	54·5	48·7	42·6	41·0
1837.	38·8	41·7	36·9	40·2	48·9	59·0	62·3	61·4	56·1	51·9	42·4	42·6
1838.	30·5	34·3	42·6	42·7	51·8	58·1	61·5	60·9	55·5	51·3	42·1	40·0
1839.	38·8	40·5	40·1	42·0	51·0	59·6	61·2	60·2	56·7	50·2	46·0	41·0
1840.	40·6	39·5	38·7	48·9	54·6	55·2	59·0	63·4	55·2	48·1	44·7	34·7
1841.	36·1	36·6	47·9	47·4	57·9	57·2	59·0	61·3	58·5	50·7	44·5	42 0
1842.	34·8	42·2	45·4	45·7	54·3	64·2	61·5	66·6	57·5	47·2	44·2	45·3
1843.	41·3	37·5	43·6	48·6	52·8	56·4						

By taking the means of the numbers in this table in different groups of years the next Table is formed.

TABLE II.—Showing the mean temperature of the Air in each month in successive groups of years.

Period.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
From 1774 to 1781	35°·0	40°·4	45°·1	48°·0	54°·4	60°·7	64°·4	62°·8	58°·1	51°·0	43°·0	40°·2
From 1787 to 1796	37·5	40·8	41·5	47·3	52·7	57·2	61·6	61·7	56·8	50·2	42·5	39·1
From 1797 to 1806	38·4	38·9	41·6	48·9	53·4	58·4	61·9	62·7	57·8	49·9	43·3	39·9
From 1807 to 1816	35·4	40·1	41·4	45·8	52·8	57·2	61·2	60·8	57·6	51·4	42·3	40·2
From 1817 to 1826	38·6	40·3	43·0	47·9	53·1	59·2	62·7	62·2	58·5	50·9	45·7	41·1
From 1827 to 1836	37·7	39·7	43·3	47·2	54·8	59·9	63·6	61·3	56·7	51·4	44·2	41·5
From 1837 to 1843	37·7	38·9	42·1	45·1	53·1	58·2	60·9	62·3	56·6	49·9	44·6	40·9

The mean temperature of January from all the observations is . . . 37°·2
The mean temperature of February from all the observations is . . 40·1
The mean temperature of March from all the observations is . . . 42·5
The mean temperature of April from all the observations is . . . 46·9
The mean temperature of May from all the observations is . . . . 53·5
The mean temperature of June from all the observations is. . . . 58·7
The mean temperature of July from all the observations is . . . . 62·4
The mean temperature of August from all the observations is . . . 62·1
The mean temperature of September from all the observations is . . 57·5
The mean temperature of October from all the observations is . . 50·7
The mean temperature of November from all the observations is . . 44·0
The mean temperature of December from all the observations is . . 40·4
The mean of all the monthly results is . . . . . 49·7

I shall not attempt to enter into the discussion of periods of less or greater heat, as such can be very readily seen in the following Table, which is formed by taking the difference between the mean temperature of the month derived from all the observations, and the mean temperature of the same month in every year, as contained in Table I.

TABLE III.—Showing the excess of the monthly mean temperature, in every year, above the mean temperature of the month, as deduced from all the years.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
	°	°	°	°	°	°	°	°	°	°	°	°
1774.	− 4·1	−0·7	+1·4	+1·0	−1·3	+2·3	+0·4	−0·6	−1·7	−0·6	−3·5	− 1·9
1775.	+ 4·8	+3·2	+0·3	+3·9	+1·7	+4·8	+1·6	0·0	+2·0	−1·2	−2·5	+ 0·3
1776.	− 8·6	+1·3	+2·3	+1·4	−1·8	+0·9	+1·4	−0·1	−1·9	+2·1	0·0	+ 1·1
1777.	− 1·7	−2·9	+3·2	−1·8	−0·1	−1·5	−0·9	+1·6	+1·7	+1·9	+1·0	− 3·2
1778.	− 0·8	−3·1	−1·3	+1·1	+2·4	+3·5	+5·6	+2·7	−2·0	−3·4	+2·0	+ 3·8
1779.	− 0·8	+6·6	+5·6	+4·9	+2·3	+0·2	+3·5	+3·1	+4·3	+2·5	−0·8	+ 1·2
1780.	− 7·0	−2·4	+7·8	−2·2	+3·7	+1·3	+1·8	+4·9	+2·9	+0·6	−3·2	− 2·4
1781.	+ 0·6	+1·6	+1·2	+0·3	+0·7	+4·7	+3·9	+2·2				
1787.	+ 1·1	+0·8	+1·4	−1·4	−1·1	0·0	0·0	+0·3	−2·0	−0·8	−3·1	+ 0·6
1788.	+ 1·8	0·0	−2·8	+3·7	+3·9	+0·8	−0·8	−0·9	−0·5	−0·3	−2·1	−10·0
1789.	− 2·2	+1·2	−7·0	−1·7	+0·8	−3·0	−2·6	−0·6	−1·8	−2·6	−4·0	+ 2·6
1790.	+ 3·0	+2·5	+1·8	−4·9	+0·2	−1·0	−2·3	−0·9	−2·5	+0·1	−0·7	0·0
1791.	+ 4·2	+0·1	+0·7	+3·0	−3·0	−0·2	−1·9	+0·6	+0·4	−2·8	−1·4	− 4·2
1792.	− 0·7	−1·3	+0·7	+3·1	−2·8	−3·4	−2·8	+1·4	−1·0	−0·7	+0·5	+ 1·0
1793.	− 0·3	+1·0	−2·1	−3·4	−1·7	−2·4	+3·5	−1·8	−3·6	+2·5	+0·2	+ 2·0
1794.	− 2·3	+6·0	+2·9	+3·8	−1·8	−0·2	+3·9	−1·4	−2·7	−1·1	+0·6	− 2·2
1795.	−11·7	−4·6	−2·8	−0·7	−0·5	−4·1	−2·5	0·0	+4·4	+4·0	−2·0	+ 5·8
1796.	+ 9·7	+0·9	−2·4	+2·5	−2·3	−1·7	−2·8	−0·9	+2·7	−2·9	−2·4	− 8·6
1797.	− 0·2	−3·1	−3·5	−1·1	−1·1	−3·0	+1·9	−1·8	−1·8	−2·4	−1·3	+ 2·2
1798.	+ 2·2	−0·8	−0·7	+3·4	+1·2	+3·4	−0·2	+0·7	+0·1	+0·4	−2·7	− 5·3
1799.	− 2·3	−2·3	−4·2	−4·3	−2·9	−2·2	−1·6	−3·3	−2·1	−2·1	+0·2	− 6·2
1800.	+ 1·3	−4·6	−2·9	+2·6	+1·6	−2·7	+1·8	+2·9	+1·5	−1·5	−0·5	− 0·8
1801.	+ 3·9	−0·2	+3·7	−0·4	+1·2	+0·6	−0·9	+1·7	+2·3	+1·5	−2·5	− 2·9
1802.	− 2·7	+0·2	−0·2	+2·7	−2·2	−0·2	−4·9	+4·0	+0·6	−4·9	−2·2	− 1·2
1803.	− 2·2	−2·4	+0·9	+2·0	−2·3	−1·6	+2·3	+0·9	−3·7	−0·5	−0·8	+ 4·3
1804.	+ 7·6	−1·8	−0·3	−2·1	+4·2	+3·5	−1·2	−0·9	+3·0	+2·0	+1·4	− 3·4
1805.	− 1·1	0·0	+0·6	−0·5	−2·8	−3·3	−2·3	+0·9	+2·9	−2·0	−2·8	+ 0·5
1806.	+ 5·0	+2·8	−0·7	−2·8	+2·6	+2·0	−0·2	+0·6	+0·6	+1·8	+4·7	+ 7·8
1807.	+ 1·1	+1·3	−4·4	−0·4	+2·6	−0·1	+2·1	+2·9	−3·3	+3·6	−4·0	− 2·4
1808.	+ 1·4	−2·4	−4·3	−3·3	+4·7	+0·2	+4·3	+1·7	−1·1	−2·3	+1·2	− 3·0
1809.	− 5·2	+5·4	+1·2	−4·7	+3·3	−0·3	−1·8	−1·9	−0·3	+0·2	−3·2	+ 2·0
1810.	− 1·2	−0·1	+0·8	+0·6	−2·7	+0·7	−0·5	−0·3	+3·0	+2·4	+0·1	− 0·4
1811.	− 2·9	+1·2	+1·5	+2·1	+2·9	−0·7	−1·4	−3·2	+0·8	+5·6	+2·3	− 0·6
1812.	+ 0·3	+2·9	−3·0	−4·3	−1·2	−3·8	−4·4	−3·8	−0·5	−0·6	−2·1	− 3·9
1813.	− 1·2	+2·9	+1·7	−2·0	−0·1	−2·5	−2·5	−2·5	−1·9	−2·1	−2·5	− 2·4
1814.	− 8·7	−4·7	−6·3	+2·3	−3·8	−4·4	−0·3	−2·2	−1·5	−2·1	−2·0	+ 2·1
1815.	− 3·7	+2·5	+3·6	+0·8	+2·3	+0·2	−1·5	−0·4	+5·9	+2·0	−3·8	− 2·0
1816.	+ 1·1	−2·1	−3·2	−2·4	−3·6	−4·7	−6·9	−2·9	+2·5	+1·4	−3·4	− 1·2
1817.	+ 3·6	+3·9	−0·2	−1·9	−4·5	+1·3	−2·7	−5·4	−0·9	−4·4	+4·2	− 1·9
1818.	+ 3·7	−2·9	−0·5	−0·2	+0·1	+5·1	+4·8	+2·8	+4·3	+4·3	+6·5	− 0·2
1819.	+ 4·5	+1·3	+2·6	+2·4	+1·8	−4·4	+0·3	+3·0	+1·7	−1·9	−1·9	− 2·0
1820.	− 3·9	−1·8	−0·1	+3·5	−0·4	−1·7	−1·9	−2·3	−2·0	−2·4	−1·3	+ 0·9
1821.	+ 1·9	−2·7	+1·4	+4·6	−3·0	−3·7	−3·7	+0·9	+3·2	+0·9	+4·9	+ 5·3
1822.	+ 4·2	+4·6	+5·9	+0·9	+3·4	+4·8	+1·1	+0·5	−0·4	+2·6	+5·5	− 2·6
1823.	+ 3·8	−0·6	−1·6	−3·0	+2·2	−2·4	−2·3	−1·0	−1·0	−1·8	+0·3	+ 0·9
1824.	+ 1·8	−2·5	−1·9	−2·0	−2·9	−2·8	+1·1	−0·8	+1·3	+0·4	+3·5	+ 2·8
1825.	+ 2·8	−0·6	−2·9	+2·9	+1·2	+1·1	+3·8	+1·0	+3·5	+1·4	−1·5	+ 1·6
1826.	3·6	+2·5	+1·8	+3·2	2·4	+5·1	+4·2	+2·6	−0·1	+3·0	−2·8	+ 2·8
1827.	− 2·2	−7·1	+1·7	+1·0	+0·3	−0·2	+2·1	−1·8	+0·5	+2·4	−1·2	+ 5·1
1828.	+ 4·2	+1·5	+2·1	+0·7	+1·9	+2·2	+0·5	−1·8	+1·1	+0·5	+1·6	+ 5·5
1829.	− 3·9	−0·3	−2·4	−2·1	+2·1	+1·2	−1·3	−3·1	−3·2	−1·9	−3·4	− 4·1
1830.	− 4·9	−4·5	+4·4	+2·5	+2·3	−2·5	+1·6	−2·6	−2·9	+1·5	+1·7	− 4·1
1831.	− 1·2	+2·5	+2·5	+2·3	+0·4	+1·6	+2·9	+2·5	0·0	+5·6	+1·6	+ 3·0
1832.	+ 1·7	−1·8	−0·9	+1·4	−0·9	+1·4	−0·2	+0·2	+0·2	+1·8	+1·0	+ 3·4
1833.	− 1·1	+3·7	−3·8	−0·6	+7·0	+2·0	−0·3	−3·3	−2·9	−1·1	+0·8	+ 5·6
1834.	+ 8·8	+1·5	+2·6	−3·8	−0·5	+3·3	+2·7	+1·5	+1·9	+1·1	+1·4	+ 2·0
1835.	+ 2·4	+2·5	−0·4	+0·6	+0·5	+2·2	+3·0	+2·5	+0·7	−1·4	+0·3	− 4·1
1836.	+ 1·6	−1·8	+2·3	−2·5	+0·4	+1·2	+1·5	−1·9	−3·0	−2·0	−1·2	+ 0·6
1837.	+ 1·6	+1·6	−5·6	−6·7	−4·6	+0·3	−0·1	−0·7	−1·4	+1·2	−1·6	+ 2·2
1838.	− 6·7	−5·8	+0·1	−4·2	−1·7	−0·6	−0·9	−1·2	−2·0	+0·6	−1·9	− 0·4
1839.	+ 1·6	+0·4	−2·4	−4·9	−2·5	+0·9	−1·2	−1·9	−0·8	−0·5	+2·0	+ 0·6
1840.	+ 3·4	−0·6	−3·8	+2·0	+1·1	−3·5	−2·6	+1·3	−2·3	−2·6	+0·7	− 5·7
1841.	− 1·1	−3·5	+5·4	+0·5	+4·4	−1·5	−3·4	−0·8	+1·0	0·0	+0·5	+ 1·6
1842.	− 2·4	+2·1	+2·9	−1·2	+0·8	+5·5	−0·9	+4·5	0·0	−3·5	+0·2	+ 4·9
1843.	+ 4·1	−2·6	+1·1	+1·7	−0·7	−2·3						

The sign − denotes that the temperature of that month was below the average, and the sign + denotes that it was above the average.

In the following Table the mean temperature has been taken for the quarterly periods ending March 31, June 30, September 30 and December 31; and for the year, these numbers will be immediately comparable with those now published in the Registrar-General's Quarterly and Annual Reports.

TABLE IV.—Showing the mean temperature in quarterly periods, for the year, and the same for successive groups of years.

Year.	January, February, March.	Group of years.	April, May, June.	Group of years.	July, August, September.	Group of years.	October, November, December.	Group of years.	For the year.	Group of years.
	°	°	°	°	°	°	°	°	°	°
1774.	38·4		53·7		60·0		43·0		48·9	
1775.	42·7		56·5		61·8		43·9		51·2	
1776.	38·2		53·2		60·5		46·1		49·5	
1777.	39·5		51·9		61·5		44·9		49·4	
1778.	38·2	40·2	55·4	54·4	62·3	62·1	45·8	44·7	50·5	50·2
1779.	43·4		55·5		64·3		46·0		51·5	
1780.	39·1		58·0		63·8		43·4		50·1	
1781.	41·0		54·2							
1787.	41·0		52·2		60·1		43·9		49·3	
1788.	39·6		55·8		59·9		40·9		49·1	
1789.	37·2		51·7		59·0		43·7		47·9	
1790.	42·3		51·1		58·8		44·8		49·3	
1791.	41·6		52·9		60·3		42·2		49·3	
1792.	39·5	39·9	52·0	52·3	59·8	60·0	45·3	43·9	49·2	49·1
1793.	39·4		50·5		60·0		46·6		49·2	
1794.	42·1		53·6		60·6		44·1		50·1	
1795.	33·5		51·2		61·3		47·6		48·4	
1796.	42·6		52·3		60·3		40·4		48·9	
1797.	37·7		51·3		60·1		44·5		48·4	
1798.	40·1		55·7		60·9		42·5		49·8	
1799.	37·0		49·9		58·3		42·3		46·9	
1800.	37·5		53·5		62·7		44·1		49·5	
1801.	42·1		53·5		61·7		43·7		50·2	
1802.	39·0	39·7	53·1	52·9	60·5	60·8	42·3	44·4	48·7	49·4
1803.	39·7		52·4		60·5		46·0		49·4	
1804.	41·8		54·9		60·9		45·0		50·7	
1805.	39·7		50·8		61·1		43·6		48·9	
1806.	42·3		53·6		61·0		49·8		51·7	
1807.	39·2		53·4		61·2		44·1		49·6	
1808.	38·2		53·3		62·3		43·3		49·3	
1809.	40·4		52·5		59·3		44·7		49·2	
1810.	39·8		52·8		61·4		45·7		49·9	
1811.	39·9		54·5		59·4		47·5		50·3	
1812.	40·0	39·1	49·9	52·2	57·9	59·9	42·8	44·3	47·7	48·9
1813.	41·1		51·5		58·3		42·7		48·4	
1814.	33·3		51·1		59·3		44·4		47·0	
1815.	40·7		54·1		62·0		43·7		50·2	
1816.	38·9		49·4		58·2		43·9		47·6	

Table IV. (Continued.)

Year.	January, February, March.	Group of years.	April, May, June.	Group of years.	July, August, September.	Group of years.	October, November, December.	Group of years.	For the year.	Group of years.
	°	°	°	°	°	°	°	°	°	°
1817.	42·5		51·3		57·3		44·3		48·9	
1818.	40·0		54·7		64·6		48·5		51·9	
1819.	42·7		54·0		62·3		43·1		50·5	
1820.	38·0		53·6		58·6		44·1		48·5	
1821.	40·1		55·6		60·8		48·7		50·5	
1822.	44·8	40·6	56·1	53·8	61·1	61·4	46·9	45·9	52·2	50·3
1823.	37·9		52·0		59·2		44·8		48·7	
1824.	39·0		50·5		61·2		47·2		49·5	
1825.	39·7		54·8		63·4		45·5		50·8	
1826.	40·1		55·0		62·9		46·0		51·1	
1827.	37·4		53·4		60·9		47·1		49·7	
1828.	42·5		54·6		60·6		47·6		51·3	
1829.	37·7		53·4		58·1		41·9		47·8	
1830.	38·3		53·8		59·3		44·7		49·0	
1831.	41·2		54·4		62·4		48·4		51·6	
1832.	39·6	40·2	53·7	54·2	60·7	60·1	47·1	45·8	50·3	50·1
1833.	39·5		58·5		54·5		46·8		50·0	
1834.	44·2		53·7		62·7		46·5		51·8	
1835.	41·6		54·1		62·7		43·3		50·4	
1836.	40·6		52·7		59·5		44·1		49·3	
1837.	39·1		49·4		59·9		45·6		48·5	
1838.	35·8		50·8		59·3		45·3		47·8	
1839.	39·8		50·9		59·4		45·7		48·9	
1840.	39·6	39·4	52·9	52·2	56·1	59·4	42·5	45·1	48·6	49·2
1841.	40·2		54·2		59·6		45·7		49·8	
1842.	40·8		54·4		61·9		45·6		50·7	
1843.	40·8		52·6							

The mean temperature from all the observations

For the quarter ending March . 31 was 39°·8,

„ June . . 30 was 53·1,

„ September 30 was 60·5,

„ December 31 was 44·8,

and for the year from all the observations was 49°·6.

By taking the difference between these numbers, and those contained in the preceding Table, the next Table is immediately formed.

TABLE V.—Showing the excess of the quarterly and yearly mean temperatures, in every year, above their means from all the years.

Year.	January, February, March.	April, May, June.	July, August, September.	October, November, December.	Whole year.	Year.	January, February, March.	April, May, June.	July, August, September.	October, November, December.	Whole year.
	°	°	°	°	°		°	°	°	°	°
1774.	−1·4	+0·6	−0·5	−1·8	−0·7	1811.	+0·1	+1·4	−1·1	+2·7	+0·7
1775.	+2·9	+3·4	+1·3	−0·9	+1·6	1812.	+0·2	−3·2	−2·6	−2·1	−1·9
1776.	−1·6	+0·1	0·0	+1·3	−0·1	1813.	+1·3	−1·6	−2·2	−2·1	−1·2
1777.	−0·3	−1·2	+1·0	+0·1	−0·2	1814.	−6·5	−2·0	−1·2	−0·4	−2·6
1778.	−1·6	+2·3	+1·8	+1·0	+0·9	1815.	+0·9	+1·0	+1·5	−1·1	+0·6
1779.	+3·6	+2·4	+3·8	+1·8	+1·9	1816.	−1·0	−3·7	−2·3	−0·9	−2·0
1780.	−0·7	+0·9	+3·3	−1·4	+0·5	1817.	+2·7	−1·8	−3·2	−0·5	−0·7
1781.	+1·2	+1·1				1818.	+0·2	+1·6	+4·1	+3·7	+2·3
						1819.	+2·9	+0·9	+1·8	−1·7	+0·9
1787.	+1·2	−0·9	−0·4	−0·9	−0·3	1820.	−1·8	+0·5	−1·9	−0·7	−1·1
1788.	−0·2	+2·7	−0·6	−3·9	−0·5	1821.	+0·3	+2·5	+0·3	+3·9	+0·9
1789.	−2·6	−1·4	−1·5	−1·1	−1·7	1822.	+5·0	+3·0	+0·6	+2·1	+2·6
1790.	+2·5	−2·0	−1·7	0·0	−0·3	1823.	−1·9	−1·1	−1·3	0·0	−0·9
1791.	+1·8	−0·2	−0·2	−2·6	−0·3	1824.	−0·8	−2·6	+3·7	+2·4	−0·1
1792.	−0·3	−1·1	−0·7	+0·5	−0·4	1825.	−0·1	+1·7	+2·9	+0·7	+1·2
1793.	−0·4	−2·6	−0·5	+1·8	−0·4	1826.	+0·3	+1·9	+2·4	+1·2	+1·5
1794.	+2·3	+0·5	+0·1	−0·7	+0·5	1827.	−2·4	+0·3	+0·4	+2·3	+0·1
1795.	−6·3	−1·9	+0·8	+2·8	−1·2	1828.	+2·7	+1·5	+0·1	+2·8	+1·7
1796.	+2·8	−0·8	−0·2	−4·4	−0·7	1829.	−2·1	+0·3	−2·4	−2·9	−1·8
1797.	−2·1	−1·8	−0·4	−0·3	−1·2	1830.	−1·5	+0·7	−1·2	−0·1	−0·6
1798.	+0·3	+2·6	+0·4	−2·3	+0·2	1831.	+1·4	+1·3	+1·9	+3·6	+2·0
1799.	−2·8	−3·2	−2·2	−2·5	−2·7	1832.	+0·2	+0·6	+0·2	+2·3	+0·7
1800.	−2·3	+0·4	+2·2	−0·7	−0·1	1833.	−0·3	+5·4	−6·0	+2·0	+0·4
1801.	+2·3	+0·4	+1·2	−1·1	+0·6	1834.	+4·4	+0·6	+2·2	+1·7	+2·2
1802.	−0·8	0·0	0·0	−2·5	−0·9	1835.	+1·8	+1·0	+2·2	−1·5	+0·8
1803.	−1·1	−0·7	0·0	+1·2	−0·2	1836.	+0·8	−0·4	−1·8	−0·7	−0·3
1804.	+2·0	+1·8	+0·4	+0·2	+1·1	1837.	−0·7	−3·7	−0·6	+0·8	−1·1
1805.	−0·1	−2·3	+0·6	−1·2	−0·7	1838.	−4·0	−2·3	−1·2	+0·5	−1·8
1806.	+2·5	+0·5	+0·5	+5·0	+2·1	1839.	0·0	−2·2	−1·1	+0·9	−0·7
1807.	−0·6	+0·3	+0·7	−0·7	0·0	1840.	−0·2	−0·2	−4·4	−2·3	−1·0
1808.	−1·6	+0·2	+1·8	−1·5	−0·3	1841.	+0·4	+1·1	−0·9	+0·9	+0·2
1809.	+0·6	−0·6	−1·2	−0·1	−0·4	1842.	+1·0	+1·3	+1·4	+0·8	+1·1
1810.	0·0	−0·3	+0·9	+0·9	+0·3	1843.	+1·0	−0·5			

The sign − denotes that the period was below the average, and the sign + denotes that the period was above the average.

The numbers in the last column of this table indicate the excess or defect of the temperature of that year above or below the average. The year of lowest temperature was 1799, and every month in this year was below its average value except November (see Table III.). The year of highest temperature was 1822, which by reference to Table III., was warm throughout, the months of September and December being those only whose temperatures were below their averages. The mean temperature of the year, therefore, within this period has varied from 46°·9 in 1799 to 52°·2 in 1822. The difference between these numbers is 5°·3. This amount of difference upon the whole year is very large.

The quarterly values of temperature, as found in the preceding tables, do not represent the mean value for any meteorological period; the latter values always follow the astronomical divisions of the year. In the following Table the year is supposed to

begin in March, so that every year may consist of one summer and one entire winter, and not of parts of two winters with the summer intervening, therefore—

Spring includes the months of March, April and May;
Summer includes the months of June, July and August;
Autumn includes the months of September, October and November;
Winter includes the months of December, January and February;

so that winter consists of the last month of one civil year, and the first two months of the following year.

TABLE VI.—Showing the mean temperature in Spring, Summer, Autumn and Winter, and the same for successive groups of years.

Year.	Spring.		Summer.		Autumn.		Winter.	
	March, April, May.	Group of years.	June, July, August.	Group of years.	September, October, November.	Group of years.	December, January, February.	Group of years.
	°	°	°	°	°	°	°	°
1774.	48·0		61·7		48·8		41·3	
1775.	49·3		63·2		50·2		36·9	
1776.	48·3		61·8		50·8		38·1	
1777.	48·1	49·1	60·8	63·0	52·3	50·7	36·9	38·7
1778.	48·4		65·0		49·3		42·4	
1779.	51·9		63·3		52·7		36·2	
1780.	50·7		63·7		50·8		39·2	
1781.	48·3		64·7					
1787.	47·3		61·2		48·7		40·0	
1788.	49·2		60·7		49·7		35·6	
1789.	45·0		59·0		47·9		41·9	
1790.	46·7		59·6		49·7		40·7	
1791.	47·8	46·9	60·5	60·1	49·5	49·9	37·2	38·9
1792.	46·3		59·4		50·3		39·8	
1793.	45·2		60·8		50·4		41·1	
1794.	49·2		61·8		49·6		33·1	
1795.	46·3		58·8		52·9		44·7	
1796.	45·9		59·3		49·8		35·3	
1797.	45·7		60·1		48·9		40·0	
1798.	48·9		62·3		50·0		38·6	
1799.	43·8		58·7		49·4		36·1	
1800.	47·7		61·7		50·5		40·2	
1801.	48·8	47·3	61·5	60·9	51·1	50·3	37·4	39·5
1802.	47·7		60·7		48·5		37·3	
1803.	47·8		61·6		49·1		42·6	
1804.	48·2		61·5		52·7		37·7	
1805.	46·7		59·5		50·1		42·0	
1806.	47·3		61·8		53·1		42·6	
1807.	46·0		62·6		47·6		38·1	
1808.	46·7		63·1		49·6		38·3	
1809.	47·5		59·7		49·6		39·4	
1810.	47·2		57·3		52·6		38·5	
1811.	49·8	46·6	59·3	59·4	53·6	50·4	40·1	38·6
1812.	44·8		57·2		49·6		38·5	
1813.	44·2		58·5		49·2		33·9	
1814.	45·0		58·7		48·8		39·5	
1815.	50·2		60·5		52·1		38·2	
1816.	44·9		56·2		50·9		41·3	

TABLE VI. (Continued.)

Year.	Spring.		Summer.		Autumn.		Winter.	
	March, April, May.	Group of years.	June, July, August.	Group of years.	September, October, November.	Group of years.	December, January, February.	Group of years.
	°		°		°		°	
1817.	44·5		58·4		50·3		38·9	
1818.	47·4		65·3		55·7		41·1	
1819.	49·9		61·7		50·0		36·7	
1820.	48·6		59·1		48·8		39·3	
1821.	48·6		58·9		53·7		43·9	
1822.	51·0	47·9	63·2	61·4	53·3	51·7	36·9	40·4
1823.	46·8		59·2		49·9		39·3	
1824.	45·3		60·2		52·5		40·9	
1825.	48·0		63·0		51·0		39·7	
1826.	48·5		65·0		50·8		37·1	
1827.	48·6		61·1		51·6		42·8	
1828.	49·2		61·4		51·8		39·6	
1829.	46·8		60·0		47·9		34·7	
1830.	50·7		59·9		50·8		38·3	
1831.	49·3		63·4		53·1		40·2	
1832.	47·5	48·4	61·5	61·6	51·7	50·8	41·2	40·1
1833.	48·5		59·8		49·7		44·5	
1834.	48·1		63·5		52·2		41·5	
1835.	47·9		63·6		50·6		37·8	
1836.	47·7		61·3		48·6		40·5	
1837.	42·1		60·9		50·1		35·8	
1838.	45·7		60·2		50·5		39·8	
1839.	44·4		60·3		50·9		40·3	
1840.	47·4	46·8	59·4	60·7	49·3	49·7	35·8	38·7
1841.	51·1		59·2		51·2		39·6	
1842.	48·5		64·1		46·3		41·3	
1843.	48·3							

The mean temperature for Spring from all the observations was . . . . 47°·6
The mean temperature for Summer from all the observations was . . . 61·0
The mean temperature for Autumn from all the observations was . . . 50·5
The mean temperature for Winter from all the observations was . . . 39·3
The mean temperature for the Year from all the observations was . . . 49·6

By taking the difference between the mean temperature of each period from all the observations, and the mean temperature for the same period in every year, the following Table was formed.

TABLE VII.—Showing the excess of the mean temperature in Spring, Summer, Autumn and Winter, in every year, above the mean temperature for the period.

Year.	Spring.	Summer.	Autumn.	Winter.	Year.	Spring.	Summer.	Autumn.	Winter.
	°	°	°	°		°	°	°	°
1774.	+0·4	+0·7	−1·7	−2·0	1811.	+2·2	−1·7	+3·1	+0·8
1775.	+1·7	+1·2	−0·3	−2·4	1812.	−2·8	−3·8	−0·9	−0·8
1776.	+0·7	+0·8	+0·3	−1·2	1813.	−3·4	−2·5	−1·3	−5·4
1777.	+0·5	−0·2	+1·8	−2·4	1814.	−2·6	−2·3	−1·7	+0·2
1778.	+0·8	+4·0	−1·3	+3·1	1815.	+2·6	−0·5	+1·6	−1·1
1779.	+4·3	+2·3	+2·2	−3·1	1816.	−2·7	−4·8	+0·4	+2·0
1780.	+3·1	+2·7	+0·3	−0·1	1817.	−3·1	−2·6	−0·2	−0·4
1781.	+0·7	+3·7			1818.	−0·2	+4·3	+5·2	+1·8
					1819.	+2·3	+0·7	−0·5	−2·6
1787.	−0·3	+0·2	−1·8	+0·7	1820.	+1·0	−1·9	−1·7	0·0
1788.	+1·6	−0·3	−0·8	−3·7	1821.	+1·0	−2·1	+3·2	+4·6
1789.	−2·6	−2·0	−2·6	+2·6	1822.	+3·4	+2·2	+2·8	−2·4
1790.	+0·9	−1·4	−0·8	+1·4	1823.	−0·8	−1·8	−0·6	0·0
1791.	+0·2	−0·5	−1·0	−2·1	1824.	−2·3	−0·8	+2·0	+1·6
1792.	−1·3	−1·6	−0·2	+0·5	1825.	+0·4	+2·0	+1·5	+0·4
1793.	−2·4	−0·2	−0·1	+1·8	1826.	+0·9	+4·0	+0·3	−2·2
1794.	+1·6	+0·8	−0·9	−6·2	1827.	+1·0	+0·1	+1·1	+3·5
1795.	−1·3	−2·2	+2·4	+5·4	1828.	+1·6	+0·4	+1·3	+0·3
1796.	−1·7	−1·7	−0·7	−4·0	1829.	−0·8	−1·0	−2·6	−4·6
1797.	−1·9	−0·9	−1·6	+0·7	1830.	+3·1	−1·1	+0·3	−1·0
1798.	+1·3	+1·5	−0·5	−0·7	1831.	+1·7	+2·4	+2·6	+0·9
1799.	−3·8	−2·3	−1·1	−3·2	1832.	−0·1	+0·5	+1·2	+1·9
1800.	+0·1	+0·7	0·0	+0·9	1833.	+0·9	−1·2	−0·8	+5·2
1801.	+1·2	+0·5	+0·6	−1·9	1834.	+0·5	+2·5	+1·7	+2·2
1802.	+0·1	−0·3	−2·0	0·0	1835.	+0·3	+2·6	+0·1	−1·5
1803.	+0·2	+0·6	−1·4	+3·3	1836.	+0·1	+0·3	−1·9	+1·2
1804.	+0·6	+0·5	+2·2	−1·6	1837.	−5·5	−0·1	−0·4	−3·5
1805.	−0·9	−1·5	−0·4	+2·7	1838.	−1·9	−0·8	0·0	+0·5
1806.	−0·3	+0·8	+2·6	+3·3	1839.	−3·2	−0·7	+0·4	+1·0
1807.	−1·6	+1·6	−2·9	−1·2	1840.	−0·2	−1·6	−1·2	−3·5
1808.	−0·9	+2·1	−0·9	−1·0	1841.	+3·5	−1·8	+0·7	+0·3
1809.	−0·1	−1·3	−0·9	+0·1	1842.	+0·9	+3·1	−4·2	+2·0
1810.	−0·4	−3·7	+2·1	−0·8	1843.	+0·7			

The sign − denotes that the mean temperature for that period was below the average, and the sign + denotes that it was above the average.

It will be seen that hitherto the mean temperature at Somerset House has been estimated a great deal too high; in almost every case the corrections have reduced the temperature. I have not in this paper discussed the question whether the temperature, as now determined, is too high for the latitude and elevation of Somerset House. This discussion will be necessary when I attempt to connect the series at Greenwich (which I look upon as merely a continuation of that taken at the Royal Society) with these results. I have already made some progress in this investigation, and hope in a short time to present to the Society the results of my labours, and to give similar results to those in this paper brought up to the present time. At some future time I hope to be able to reduce the barometrical observations in a similar manner, the results from which will be of great value; for although there has been neglect in stating at different times, what corrections have, and what have not been applied, yet I think they admit of the deduction of valuable results.

XVII. *On the Meteorology of the Lake District of Cumberland and Westmoreland; including the results of Experiments on the fall of Rain at various heights, up to 3166 feet above the sea level.*

By John Fletcher Miller, *Esq., F.R.A.S.*

Communicated by Lieut.-Col. Sabine, *For. Sec. R.S.*

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THE form of the instruments, their positions, &c., are fully described in a former paper, read before the Royal Society on the 18th of May 1848.

The Roman numerals attached to each gauge refer to corresponding numbers on a map of the Lake District accompanying the said paper.

With one exception, elsewhere referred to, no accident of any importance has occurred to interrupt the continuity or correctness of the rain tables. Indeed, considering the extent of the experiments, and the exposed position of many of the instruments, mishaps of any kind have from the first been exceeding rare. The gauges are all under my own supervision; the registrars are all thoroughly instructed in the method of reading off the rain, which is regularly recorded in registers prepared for the purpose; and, being all careful persons, and almost constantly on the spot, the observations are seldom omitted even for a single day.

The records are transmitted to me at the close of each month, and are entered in collateral columns in a large folio journal; should there be any apparent discrepancy at any station on any particular day or days, an explanation is requested, and the original register examined, to ascertain whether the transmitted copy is correct. In this way, errors have occasionally, though very rarely, been discovered, and I do not recollect that one such has occurred during the past year.

The Observatory, Whitehaven,
February 6, 1849.

TABLE I.—Synopsis of the Fall of Rain in the Lake Districts of Cumberland and Westmoreland, for the year 1848.

No.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	XX.	Prevailing winds.		
	Whitehaven.											Eskdale.			Westmoreland.			Borrowdale.					
1848.	High Street, 90 feet above the sea.	Round Close, 400 feet above the sea.	St. James's Church Steeple, 76 feet above the sea.	The Flosh, three miles north of Whitehaven.	Cockermouth.	Bassenthwaite Halls, 210 feet above the sea.	Keswick, 228 feet above the sea.	Vale of Gilderdale-waite, Ennerdale, 240 feet above the sea.	Loweswater, 226 feet above the sea.	Foot of Crummock Lake, 283 feet above the sea.	Gatesgarth, 226 feet above the sea.	Centre Vale.	Head Vale.	Wrasdale Head, 166 feet above the sea.	The Hare, Troutbeck, 300 feet above the sea.	Ambleside, 182 feet above the sea.*	Langdale Head, 250 ? feet above the sea.	Seathwaite. In Garden, 6 inches above the surface.	Seathwaite. In Field, 18 inches above the surface.	Stonethwaite.	At Crummock Lake, two observations daily.	At Seathwaite one observation daily.	At the coast, two observations daily.
January	in. 3·745	in. 3·735	in. 3·303	in. 4·34	in. 3·80	in. 3·42	in. 4·112	in. 7·20	in. 5·184	in. 7·30	in. 8·25	in. 4·92	in. 6·35	in. 6·06	in. 5·922	in. 4·72	in. 7·01	in. 9·67	in. 9·63	in. 7·86	E.	variable.	S.E.& S.W.
February	7·815	7·986	6·397	9·82	9·73	8·11	10·276	16·93	12·971	14·48	24·78	11·70	14·22	19·92	19·903	14·19	25·67	30·55	29·98	22·90	S.W.	W.	S.W. & W.
March	4·588	3·930	3·498	5·38	3·80	3·00	4·736	7·30	5·706	6·77	8·57	5·56	6·70	9·15	6·834	5·85	9·71	11·36	11·18	8·86	S.W.	W. & S.W.	N.E.
April.....	·495	·339	·293	·87	1·00	2·23	1·722	3·00	1·627	2·83	3·54	1·87	2·82	3·24	1·927	2·30	3·32	4·19	4·12	3·49	E.	variable.	N.E.
May	1·788	1·612	1·452	2·23	·71	·53	1·062	3·40	1·175	1·52	3·17	1·01	1·83	1·54	1·852	2·03	2·11	3·05	2·97	3·03	S.W.	W.	S.W.
June.....	3·867	4·041	3·043	5·24	4·36	3·53	5·036	6·16	6·236	7·17	8·31	6·43	6·34	9·87	6·478	5·74	9·86	11·30	11·19	9·82	S.W.	S.W.	S.W.
July	3·630	3·862	2·442	4·60	4·10	3·45	6·246	9·58	7·431	10·41	13·66	5·98	7·21	10·66	6·080	6·18	12·12	17·76	17·53	14·34	S.W.	S.W.	W.
August	5·054	5·501	4·188	8·07	7·31	4·72	6·280	9·26	7·795	9·73	11·37	7·45	8·42	10·74	7·488	7·16	11·41	13·91	13·54	10·36	S.W.	S.W.	W.
September ..	2·266	2·122	1·723	2·72	2·51	2·21	2·104	4·86	3·755	4·63	5·43	3·72	3·99	5·47	3·257	2·80	4·84	7·00	6·92	4·88	S.W. var.	S.W. var.	S.W.
October	5·772	5·676	4·632	8·36	4·44	5·12	7·158	9·70	8·134	11·11	13·72	7·67	9·90	11·88	9·357	9·89	13·53	17·32	16·81	14·27	S.	S. var.	S.W.
November...	3·507	3·412	2·186	4·07	4·80	4·77	6·703	9·60	6·552	7·62	12·40	6·13	7·97	11·10	9·954	6·66	13·13	14·07	13·54	11·38	N.W. var.	N.W. & S.W.	N.W. var.
December...	4·805	4·484	3·187	5·12	5·81	5·97	10·972	10·74	10·102	14·50	18·35	7·74	11·03	15·69	12·295	10·06	17·67	20·71	19·81	19·05	S. & S.E.	S.W.	S.W.
1848.	47·342	46·700	36·344	60·82	52·37	47·06	66·407	97·73	76·668	98·07	133·55	70·38	86·78	115·32	91·347	77·58	130·38	160·89	157·22	130·24	S.W.	S.W.	S.W.
1847.	42·921	42·023	30·713	47·80	42·55	44·45	58·286	80·13	66·296	82·32	106·25	58·66	74·93	96·34	78·004	.....	112·95	129·24	126·80	106·21	westerly	S.W.	S.W.
1846.	49·134	.....	35·422	55·16	52·41	.....	67·678	83·87	79·249	96·47	121·90	.....	.....	106·93	77·719	.....	127·40	143·51					
1845.	49·207	.....	33·489	53·00	46·93	.....	62·902	76·88	69·542	87·48	124·13	.....	.....	108·55	76·305	.....	136·00	151·87					
1844, July to December	18·561	.....	14·550	19·87	.....	.....	21·781	27·46	25·650	30·71	39·44	.....	.....	41·51	25·576								

* The gauge at Grasmere, which in the Tables and Map accompanying the Report for 1847 was marked No. XVI., has been discontinued, and Ambleside is inserted in its place.

Table II.

Wet Days.

1848.	Whitehaven.	The Flosh.	Cockermouth.	Bassenthwaite Halle.	Keswick.	Lowes water Lake.	Crummock Lake.	Eskdale.	Wastdale Head.	Troutbeck.	Langdale Head.	Seathwaite.	Stonethwaite.
January ...	13	13	15	14	15	10	12	11	15	7	13	14	14
February...	23	23	25	25	23	25	23	22	24	23	23	25	23
March.....	23	22	25	19	26	26	23	24	26	26	24	24	24
April	16	12	16	13	16	13	12	14	18	13	13	16	16
May	6	7	6	4	10	8	6	6	8	10	7	11	11
June	19	19	20	17	20	18	19	19	22	18	20	19	21
July.....	18	18	19	15	17	18	17	17	21	16	18	19	18
August ...	19	23	23	18	23	23	24	23	25	24	24	25	22
September.	13	11	15	11	10	14	14	10	16	10	12	16	13
October ...	22	22	24	26	27	23	21	21	24	18	21	22	23
November..	20	20	22	18	24	21	18	21	23	18	19	22	21
December..	18	17	18	16	18	18	18	17	21	18	18	19	18
1848.	210	207	228	196	229	217	207	205	243	201	212	232	224
1847.	191	183	210	199	204	190	199	.....	226	188	209	202	195
1846.	200	208	234	.....	213	198	216	.....	234	194	213	219	
1845.	193	175	212	.....	195	195	202	.....	211	180	.....	211	

Table III.

Showing the Quantity of Rain received by the Mountain Gauges in thirteen months, between the 1st of December 1847, and the 31st of December 1848.

No.	XXI.	XXII.	XXIII.	XXIV.	XXV.	XIV.	XIII.	XXVI.	XIX.
						Valley.		Borrowdale.	
1848.	Sca Fell, 3166 feet above the sea.	Great Gabel, 2925 feet above the sea.	Sparkling Tarn, 1900 feet above the sea.	Stye Head, 1290 feet above the sea.	Brant Rigg, about 500 feet above the sea.	To the west, Wastdale, 166 feet above the sea.	To the south-east, Eskdale, height unknown.	Seatollar Common, 1334 feet above the sea.	The Valley, Seathwaite, 242 feet above the sea.
	in.	in.	in.	in.	in.	in.	in.	in.	in.
December..	.....	Frozen	Frozen	Frozen.	Frozen	12·15	8·93	12·53	20·33
1848.	.....								
January ...	.....	Frozen	Frozen	Frozen.	Frozen	6·06	6·35	Frozen.	9·63
February...	.....	Frozen	39·45	41·31	32·65	19·92	14·22	34·18	29·98
March.....	.....	28·00	8·04	9·17	9·36	9·15	6·70	7·10	11·18
April	.....	2·29	2·31	3·22	5·84	3·24	2·82	2·07	4·12
May	*4·42	2·60	3·72	3·10	1·98	1·54	1·83	2·80	2·97
June	8·58	9·00	11·52	9·40	7·80	9·87	6·34	10·00	11·19
July.....	10·65	10·32	17·40	13·18	8·12	10·66	7·21	15·00	17·53
August ...	9·74	9·79	13·09	12·31	9·16	10·74	8·42	11·55	13·54
September..	5·11	5·39	8·16	7·51	4·76	5·47	3·99	5·42	6·92
October ...	10·96	9·71	17·06	14·85	11·36	11·88	9·90	13·20	16·81
November..	6·81	6·17	11·44	11·34	9·36	11·10	7·97	12·63	13·54
December..	8·46	8·05	16·40	13·33	8·80	15·69	11·03	13·00	19·81
Inches... { From May }	64·73	91·32	148·59	138·72	109·19	127·47	95·71	139·48	177·55

* The fall of rain at this station, during the winter of 1847–48, was lost, in consequence of injury sustained by the receiver from the frost.

Table IV.—For the Summer Months.

No.	XXI.	XXII.	XXIII.	XXIV.	XXV.	XIV.	XIII.	XXVI.	XIX.
						Valley.		Borrowdale.	
1848.	Sca Fell, 3166 feet above the sea.	Great Gabel, 2925 feet above the sea.	Sparkling Tarn, 1900 feet above the sea.	Stye Head, 1290 feet above the sea.	Brant Rigg, about 500 feet above the sea.	To the west of Wastdale	To the south-east of Eskdale.	Seatollar Common, 1334 feet above the sea.	The Valley, Seathwaite, 242 feet above the sea.
	in.	in.	in.	in.	in.	in.	in.	in.	in.
May	4·42	2·60	3·72	3·10	1·98	1·54	1·83	2·80	2·97
June	8·58	9·00	11·52	9·40	7·80	9·87	6·34	10·00	11·19
July	10·65	10·32	17·40	13·18	8·12	10·66	7·21	15·00	17·53
August	9·74	9·79	13·09	12·31	9·16	10·74	8·42	11·55	13·54
September	5·11	5·39	8·16	7·51	4·76	5·47	3·99	5·42	6·92
October	10·96	9·71	17·06	14·85	11·36	11·88	9·90	13·20	16·81
Inches	49·46	46·81	70·95	60·35	43·18	50·16	37·69	57·97	68·96

Table V.—For the Winter Months.

1847.	Sca Fell.	Great Gabel.	Sparkling Tarn.	Stye Head.	Brant Rigg.	The Valley.		Borrowdale.	
						To the west of Wastdale.	To the south-east of Eskdale.	Seatollar Common.	Valley. Seathwaite.
	in.	in.	in.	in.	in.	in.	in.	in.	in.
December	.....	Frozen	Frozen	Frozen	Frozen	.....	.....	12·53	20·33
1848.									
January	.....	Frozen	Frozen	Frozen	Frozen	.....	.....	Frozen	9·63
February	.....	Frozen	39·45	41·31	32·65	38·13	29·50	34·18	29·98
March	.....	28·00	8·04	9·17	9·36	9·15	6·70	7·10	11·18
April	.....	2·29	2·31	3·22	5·84	3·24	2·82	2·07	4·12
November	6·81	6·17	11·44	11·34	9·36	11·10	7·97	12·63	13·54
December	8·46	8·05	16·40	13·33	8·80	15·69	11·03	13·00	19·81
Inches	.....	44·51	77·64	78·37	66·01	77·31	58·02	81·51	108·59

TABLE VI.—Temperature at Seathwaite taken by Self-registering Thermometers made by WATKINS and HILL.

1848.	Absolute.		Mean of max.	Mean of min.	Approximate mean temperature.	Mean at 9 A.M.	On grass.				Prevailing winds.
	Max.	Min.					Min.	Mean.	Radiation.		
									Max.	Mean.	
	°	°	°	°	°	°	°	°	°	°	
January	50	9	37·43	27·50	32·46	32·71	6·5	24·56	7	2·93	Var.
February	49·5	25	44·50	36·67	40·58	40·24	19	33·74	7	2·93	w.
March.....	57·5	27	46·66	34·14	40·40	39·67	19·5	29·44	8·5	4·81	w. and s.w.
April	67	28·5	52·78	38·03	45·40	45·35	21	32·38	10·5	5·65	Var.
May	72·5	32	63·52	48·20	55·86	55·89	24	38·40	15	9·80	w.
June	75	40	63·86	50·75	57·30	57·18	29	42·36	15	8·41	s.w.
July	79	45	62·61	53·32	57·96	57·19	32	46·27	14	7·05	s.w.
August	62·5	41·5	57·99	49·87	53·93	53·48	29	40·79	15·5	9·08	s.w.
September	68	38·5	57·93	49·05	53·49	52·28	25·5	39·76	16	9·28	s.w. var.
October	60·5	29·5	50·17	43·66	46·91	46·61	18	36·01	14·5	7·96	s. var.
November	52	24	44·59	36·35	40·47	40·13	12	29·63	13·5	6·72	N.w. and s.w.
December	56	26	43·76	37·21	40·48	40·43	11	28·86	18·7	8·38	s.w.
Means at Whitehaven	62·4	30·5	52·15	42·06	47·10	46·76	20·5	35·18	12·9	6·91	s.w.
	62·5	33·0	53·62	44·00	48·81	.....	23·1	37·24	.....	6·76	Var.
Difference	0·1	2·5	1·47	1·94	1·71	.....	2·6	2·06	.....	0·15	
Difference in 1847.....	0·5	3·8	0·96	1·46	1·22						

Remarks.

The fall of rain in the Lake District during the year 1848, greatly exceeds the amount in any other year since the register was commenced in 1844; and the same remark applies to the number of wet days. The total depth in 1848, at Seathwaite, the wettest station, is 160·89 inches, and of this quantity, 114·32 inches fell in the six months comprehending February, July, August, October, November and December.

The wettest quarter of the year was the last, in which 52·10 inches were measured; the wettest month in 1848 was February, which yielded 30·55 inches, by far the largest quantity ever measured in any month in this country; and the two wettest days were the 3rd and 26th of December, when 4·60 and 4·22 inches respectively, were read off.

At Seathwaite, there have been forty-eight days in last year wherein the quantity of rain fallen was between half an inch and 1 inch; thirty-two days between 1 and 2 inches; thirteen days between 2 and 3 inches; five days between 3 and 4 inches; and two days between 4 and 5 inches.

In a former paper which I had the honour to lay before the Royal Society, I endeavoured to give a general outline of the meteorology of the Lake District, as far as the facts then ascertained would permit. I now proceed to discuss one or two points which were intentionally passed over in that report.

The mountains flanking the Lake District valleys, generally increase in altitude

with great regularity, towards the head or eastern extremity of the vale; and it is here that the greatest depth of rain is invariably found. The difference in the annual quantity between places contiguous to each other and in the same valley, is often remarkably great. The amount increases rapidly as we recede from the sea, and towards the head of the valley the incremental ratio is enormous.

Loweswater, Buttermere and Gatesgarth, in the same line of valley, are about two miles apart from each other; yet in 1848 Loweswater has received 76 inches, Buttermere 98 inches, and Gatesgarth 133½ inches of water. Here in a space of four miles, we have a difference of 57 inches in twelve months, and in some years the proportional excess is still greater. The head of Eskdale receives fully one-fourth more rain than the middle of the valley, and a like difference obtains between two stations in the Vale of Borrowdale about a mile apart, whilst the proportion between the deposit at Ennerdale Lake and a farm-house three miles to the westward, is as two to one nearly.

At an early stage of this inquiry, I was forcibly struck with the rapid increment in the fall towards the head or terminal point of all valleys, and I made some experiments in order to ascertain whether the effect was appreciable at much shorter distances than any of those just referred to. For this purpose I caused a duplicate gauge to be made, in all respects exactly similar to the one at Wastdale Head, and fixed it about 200 yards higher up the valley. The two gauges were read off daily at the same hour for twelve months, and the following are the results:—

Wastdale Head.

1845.	No. 1.	No. 2.	Difference.
	in.	in.	in.
October	12·35	11·89	0·46
November	12·31	11·90	0·41
December	16·18	15·78	0·40
1846.			
January	12·97	12·47	0·50
February	6·60	6·58	0·02
March	10·35	10·07	0·28
April	6·59	6·16	0·43
May	3·65	3·44	0·21
June	5·33	4·88	0·45
July	16·82	16·59	0·23
August	8·96	8·97	−0·01
September	3·79	3·64	0·15
Inches	115·90	112·37	3·53

It will be observed that the higher gauge, marked No. 1, is always in excess, and that the difference in a single month sometimes amounts to half an inch, though the instruments are within two or three fields' breadth of each other. Here the effect of a slight increase in proximity to the higher mountains is very apparent.

Temperature.—The mountain valleys are commonly supposed to be intensely cold, particularly in the winter season; but the thermometer, so far from countenancing

this opinion, shows that the inhabitants enjoy a milder and more equable climate than those who reside in the open country. The town of Whitehaven, from its proximity to the sea on the west coast, is well known to have a much higher mean temperature than is due to its latitude; it is also much less subject to those great and sudden fluctuations of heat and cold to which inland places are liable. Yet the mean temperature at Seathwaite, in the heart of the lake country, is only about 1°·5 lower than with us. In 1847 and 1848 the mean temperature of Seathwaite was 47°·46 and 47°·10, whilst at Kendal it was 46°·67 and 46°·32 respectively.

In winter, the mean of the night temperature is several degrees higher than at Cockermouth in the open plain, where the frost is much more severe. The indications of the thermometer are in accordance both with the assertions of the residents and with my own observation; for in travelling to the lakes, where the roads over the commons were frozen hard, I have often found them quite soft and clammy on arriving amongst the hills.

These valleys not only have a higher winter temperature than many localities greatly to the south of them, but they very rarely experience those low extremes which not unfrequently occur in the southern counties of England. The mean temperature of the winter months at Chiswick, in Middlesex, is nearly the same as in the Lake District, whilst a much greater extreme of cold is frequently felt there than in the north. In the neighbourhood of the metropolis the thermometer sometimes indicates a degree of cold almost unknown in these districts. Thus, on the night between the 11th and 12th of February 1847, the temperature at Greenwich fell to 6°, at Chiswick to 4°, and at Uckfield, Sussex, to 1°; when at Seathwaite the minimum was 24°·5, and the minimum for the month 20°.

The lakes, by absorbing heat in the summer and giving it out in the winter months, added to that radiated from the rocky mountain breasts, and, above all, the caloric evolved in a sensible form by the condensation of such enormous volumes of vapour, no doubt tend greatly to modify the climate of these sequestered localities.

Temperature on Sca Fell.—Last summer I stationed a pair of Rutherford's self-registering thermometers (previously compared with a standard) on the top of Sca Fell Pike; they are suspended in a deal box, having the sides and base riddled with small circular holes, so that the instruments are freely exposed to the air, and at the same time thoroughly protected from the effects of terrestrial radiation. On the summit of the Pike is a cairn, or large pile of stones about 8 feet in height, having a stout pole in the centre, which projects about 2 feet above the top of the pile. To this pole the box containing the thermometers is firmly fixed.

From the maximum thermometer I have never been able to obtain any correct readings, as, from some cause, the steel needle is always found at the extreme end of the stem, furthest from the bulb. I cannot account for this, unless indeed the fine steel needle is affected by electrical currents at such an extreme height in the clouds. The readings of the maximum thermometer would, however, have probably been of

little value, as it would be almost impossible to protect it from the effect of solar radiation.

The following are the readings of the minimum thermometer for each month from July to the end of the year 1848 :—

July, 22°; August, 24°; September, 18°; October, −6°; November, −6°; December, −9°, or 41° below the freezing-point of water*.

The lowest extreme in these months, in the Vale of Borrowdale, at 4 feet above the ground, was as under :—

July, 45°; August, 41°·5; September, 38°·5; October, 29°·5; November, 24°; December, 26°.

The Mountain Gauges.—The results are in strict accordance with those of the two previous years, and confirm the correctness of the conclusion drawn from them in a former paper, "that the quantity of rain increases from the valley upwards to an altitude of about 2000 feet, above which it begins to diminish."

Thus, in thirteen months,—

		Inches.
The Valley . . .	160 feet above sea, has received	127·47
Stye Head . . .	1290 feet above sea, has received	138·72
Seatollar Common	1334 feet above sea, has received	139·48
Sparkling Tarn .	1900 feet above sea, has received	148·59
Great Gabel . .	2925 feet above sea, has received	91·32

I regret to state that the whole quantity of water collected in the Sca Fell gauge during the winter of 1847–48 was lost, in consequence of injury caused by the frost. In the spring of last year I had a new set of receivers constructed for these stations, which are made of very heavy sheet copper, double-lapped at the seams, and with the bottoms convex inwards, to enable them the better to bear the expansive force of the water during its conversion into ice; so that a similar accident is not likely to occur again.

From the table for the summer months, it appears that between the 1st of May and the 31st of October, the gauge at 1290 feet has received 20½ per cent. more rain than the valley; at 1334 feet, 15½ per cent. more; at 1900 feet, 41½ per cent. more; at 2928 feet, 6 per cent. *less*; and at 3166 feet, about 1 per cent. *less* than the valley. The excess over the valley is somewhat greater at all the stations than in the two previous years, and Sca Fell, which usually obtains *less* rain than Gabel, has this summer received *more*.

By referring to the table for the winter months, we find that the station at 1290 feet has obtained 0·5 per cent. more rain than the valley; at 1334 feet, 5½ per cent.

* On the 29th and 31st of January 1849, the box containing the thermometers was so thickly encased in ice, that it could not be opened. The minimum temperature for the month was read off on the 12th of February, being no less than 34° below the zero point of Fahrenheit's scale. This unheard-of extreme of cold undoubtedly occurred on the night between the 2nd and 3rd of January, when a naked thermometer on grass, at Whitehaven, fell to +4°, and one on raw wool to −2°·8.—J. F. M.

more; at 1900 feet, 1½ per cent. more; and at 2928 feet, 42½ per cent. *less* than the valley. Here the gauge at 1334 feet, which on the average of the two preceding winters received the same quantity as the Vale of Wastdale, has obtained 5½ per cent. more, whilst the proportions indicated by all the other gauges are less than in 1846 and 1847.

It will also be observed that the stations at 1290 and 1334 feet, which in summer receive much less rain than at 1900 feet, in the winter months receive more. This deficiency is obviously owing to the greater proportion of snow deposited at and lost to the instrument at the higher station.

Now, as in the winter months the mountain gauges give no indication of a large proportion of the fall of snow, all of which is secured to the valley stations by their being daily examined, in order to show fairly the gradation from the valley upwards, we must exclude those months, and take in as elements in the calculation, the summer months only.

Annexed are the receipts of the mountain gauges and those of the adjacent valleys, during the summer of 1848:—

	inches.
Stye Head, 1290 feet above the sea	60·35
Seatollar Common, 1334 feet above the sea	57·97
Sparkling Tarn, 1900 feet above the sea	70·95
Great Gabel, 2925 feet above the sea	46·81
Sca Fell Pike, 3166 feet above the sea	49·46
Wastdale, the nearest valley	50·16
Eskdale Head, valley to the S.S.E., 3½ miles distant	37·69
Eskdale, centre of valley to the S.S.E., 5½ miles distant	32·46
Ennerdale, valley to the N.W., 3¾ miles distant	42·96
Loweswater, valley to the N.N.W., 7½ miles distant	34·52
Buttermere, valley to the N.N.W., 4½ miles distant	44·57
Gatesgarth, valley to the N., 2½ miles distant	57·66

It will be perceived that the increase in the warmer months up to 2000 feet, is great and rapid; and even at the highest attainable elevation in England, the quantity of rain in those months which are free from snow, considerably exceeds the deposit in most of the circumjacent valleys. Indeed (Langdale and Seathwaite excepted) Gatesgarth is the only place which materially exceeds Sca Fell and Gabel in quantity; but as Langdale Head is ten miles distant, and as Seathwaite, besides being several miles to the northward, exceeds enormously the wettest of the other valleys, it is obvious that it would not be fair to institute a comparison between them. If the whole of the snow which falls at the mountain stations could be secured, or an exact equivalent in water be allowed for it, there can be no doubt that the *annual* results would be similar to those for the summer months *only*; but in consequence of the greater proximity of the clouds to the earth in the winter months, the proportions with respect to the valley would probably be somewhat less.

Of late, I have always carried with me a hygrometer of known accuracy on visiting the Lake Districts, and all experiments which I have made on the hygrometrical state of the atmosphere at considerable altitudes above the sea, tend to establish the law which this investigation has brought to light, by showing that the degree of humidity increases upwards from the earth's surface, and that the condition, or combination of conditions most favourable for the condensation and precipitation of vapour in the greatest abundance, does obtain somewhere about 2000 feet above the sea level.

It is probable that the atmosphere is generally, at or near the point of saturation, at and above 2000 feet; but as the air temperature decreases with every further increase of elevation, its capacity for vapour is proportionately diminished, and consequently there will be less to precipitate than at the point where the temperature of the air and that of the dew-point first begin to balance each other.

From the nature of the research, it is quite impossible to obtain regular and connected observations on the hygroscopic state of the atmosphere at such great heights, but in course of time I hope to bring together a sufficient number of data to enable us to connect together some of those links in the great chain of causation which regulates the gradation and amount of precipitation at various altitudes above the earth's surface.

I am fully aware that the physical law indicated by these results, is at variance with the experiments of many careful observers, and with the inferences drawn from them by scientific men of the highest standing. But, with every deference to the opinions and deductions of these eminent authorities, it must be admitted that they have been arrived at from somewhat scanty materials. So far as my knowledge extends, no investigation of any extent or continuity had been made in this department of meteorology previously to that set on foot in the Lake District, about three years ago. The facts previously on record, with few exceptions, referred to comparatively moderate altitudes, mostly under 1000 feet, and as some of the experiments were made on the mountain breasts, the results would vary greatly, according to the gradient and position of the acclivity, and as the gauges were placed either on the windward or leeward side of the hill; regard must also be paid to the season of the year, for a gauge which in summer receives considerably more rain than the valley, may in winter obtain less; and where the instruments are read off at long intervals, there will be no inconsiderable loss from evaporation. Moreover, experience convinces me that little dependence can be placed on the results obtained from gauges stationed on the *side* of a hill, with whatever care they may have been secured. For there cannot be a doubt, that a pluviometer placed on the breast of a mountain, even on the windward side, will receive much less rain than it would do if stationed on a hill-top of equal elevation.

Thus, the gauge at Brant Rigg in Wastdale, about 500 feet above the sea, though on a comparative flat, but with abruptly rising ground behind it, in the summer of

last year has not only received less rain than the valley, but a smaller quantity by 6 inches than at 3166 feet on Sca Fell Pike.

At a future time I hope to follow out this inquiry more fully and systematically, by placing pluviometers at different heights on the breast of Sca Fell, with the view of ascertaining the effect produced by position on rising ground, over or under that due to the respective elevations.

It is not pretended that the law which appears to regulate the distribution of rain in the mountain district of Cumberland, will equally apply to every similar locality; it will doubtless be variously modified according to latitude, position, and many other circumstances; in some situations all trace of the law may disappear, and in others it is possible that it may be reversed.

As my sole object in this inquiry is a search after truth, should my inferences and deductions be found to be incorrect by any one who may investigate the subject more fully and successfully in another locality, I shall feel no hesitation in acknowledging the error.

In addition to the chief objects of research, I record the particulars of all extraordinary phenomena, such as thunder and hail-storms, great floods, and particularly whirlwinds (to which the district is very liable), with a distant prospect of combining the whole in a separate paper, treating of the physical geography of the Lake Country.

Whitehaven, February 6, 1849.

XVIII. *Description of an Infusory Animalcule allied to the Genus Notommata of* Ehrenberg, *hitherto undescribed.* *By* John Dalrymple, *F.R.C.S.* *Communicated by* Thomas Bell, *Sec. R.S.*

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THE animalcule I propose to describe in the present memoir bears so close a resemblance to *Notommata Syrinx* of Ehrenberg, that were there not special differences in its internal anatomy, such as I believe could not have been overlooked by that great observer, one might almost believe it to be the same animal.

The character of the genus is thus given by the Professor in the great folio of 1838:—"Animal ex Hydatinæorum familia, ocello unico occipitali, *pede bisulco, caudam furcatam referente*; et organo rotatorio, simpliciter ciliato, instructum." These characteristics are mostly taken from its external organs; but we find, on reference to the description of the animal, that it possesses an intestinal tube terminating in a cloaca or anal orifice, which appears from the plates to be situated at the point where the foot or forcipated tail emerges. The grand structural difference, then, to be remarked in the animalcule that forms the subject of the following pages, is that there exists no intestine, and therefore no *anal* orifice, nor any tail or forcipated extremity. This want of intestine removes it into a lower position, as regards animal life, and I would therefore refer it to a subgenus of Notommata, if it be even entitled to a place so high in the scale of Infusoria.

In shape it resembles a flask or bell-flower (corpore campanulato) (Plate XXXIII. fig. 1), narrower towards the head and expanded below, of such extreme transparency as to permit all the internal organs to be clearly visible, even to the contents of the stomach.

It moves slowly and equably, describing, while feeding, narrow circles in the water, so as seldom to be far out of the field of an half-inch object-glass; but when disturbed it will go off in a direct line until it again becomes quiet, or resumes its former slow circular motion. It is visible to the unassisted eye as a minute semi-transparent spot, and is readily drawn into a glass tube when it is desired to select one for examination. Its average length is rather less than half a line, and at its broadest part about the fifth of a line in breadth.

In order to convey a correct idea of its anatomy, it will be desirable to describe, first, its general appearance and the grouping of the organs, and subsequently to take the latter under the heads of the assimilative and reproductive functions.

It has already been said that in shape this animalcule resembles a bell-flower, or

flask, pellucid in the highest degree, possessing no colour except what is due to a small pink eye and to the stomach, which varies in hue according to the food, but generally of a yellowish brown hue. When seen laterally, or in profile (if one may so say), the lower part is not equally convex, for it slopes off from one side, so that the most inferior part of the outer case is somewhat oblique, and one side somewhat longer than the other. It is towards the inferior part of this longer side that an opening (Plate XXXIII. fig. 1 S), valvularly closed, is observed in profile, which, when seen in front, is represented by a semilunar slit (Plate XXXIII. fig. 2 H), whose concavity is turned downwards; this is the vaginal aperture, whence the embryo, when mature, or the ova, are expelled. Each leaf of this valve is provided with special muscles for opening it, while it appears to be kept closed partly by its own elasticity, and partly by the pressure of the fluid contained in the body of the animalcule. Upon the hyaline tegument of the body may be seen, faintly indicated, transverse or circular bands or rings (Plate XXXIII. fig. 1 R) that mark the points where folds are developed upon muscular contractions of the animal, and it is on the inner side of this tegumentary covering, at the place where the rings are seen, that the long, ribbon-shaped muscles are symmetrically attached (Plate XXXIII. fig. 1 M).

The principal movements of progression are effected by means of the ciliary or rotatory apparatus, at the head or superior extremity of the body, and which seem to be independent of the more special rotatory mechanism, whereby two currents are produced in the water, that draw within their influence the smaller animals that serve as food: on reaching the point where the two opposite moving vortices meet, the food is immediately directed backwards in a straight line intermediate between the two, and so enters the oral orifice of the animal (Plate XXXIII. fig. 1 B). There seems however to be a distinct power of selection, for the slightest lateral movement of the head of the animal enables it to avoid objects too large for admission, or which it wishes to reject.

The cilia, by which all these motions are effected, appear to be placed upon raised eminences or processes, rising at regular intervals from the upper circlet or coronet of the animal (Plate XXXIII. fig. 1 A); and when the power is feeble from exhaustion, the lashing movements of the cilia are very visible. Immediately below the oral orifice is a considerable dilatation, closed above by the union of three portions of firm integument, forming as it were a labial apparatus, or at least a mechanism for closing the mouth, which resembles very closely the visor which conceals the powerful jaws of the larvæ of the Libellulæ. Within the mouth are situated a powerful pair of forcipated jaws (Plate XXXIII. fig. 1 E) which seize the prey, and if large comminute and break it down. Each ramus of the jaw is jointed (Plate XXXIII. fig. 3) on a short arm, which is again moveable upon a central axis prolonged posteriorly; and each short arm has a curved and strong process, to which the very powerful and somewhat complicated muscles are attached. The forcipated extremities of the jaws are bifid, and may be fairly designated teeth, one being sharp and hooked, the other flat or chisel-edged,

for the purpose of comminution. A third sharp and curved tooth is observed on the centre of the long arm of the jaw. I have thought also to have observed a second much more slender and pointed pair of jaws (Plate XXXIII. fig. 3 H), but this requires confirmation. When a small animalcule is seized, a Gonium for instance, on which it feeds greedily, it is placed as it were on a firm cushion in front of, and somewhat below, the jaws, and is thus prevented from escaping beyond the action of the teeth. Opposite the jaws appears the red eye, of which a further description will be given presently.

Below the mandibular apparatus the tissues expand into a sort of membranous pharyngeal cavity (Plate XXXIII. fig. 1 F), terminating below in a funnel-like apex, leading to the œsophagus (Plate XXXIII. fig. 1 G). The pharynx is very contractile, and furnished accordingly with a muscular tissue.

The œsophagus is narrow, and, while not in the act of giving passage to the food, is closely contracted; when, however, a morsel is about to be transferred from the pharynx to the stomach, the latter organ is brought up by special muscles to within a short distance of the former, and the transfer quickly takes place down the now dilated œsophagus; and if the prey be of considerable size, it is even forced downwards by the strong action of the united jaws.

Immediately before the junction of the œsophagus with the stomach, two kidney-shaped glands (Plate XXXIII. fig. 1 H) are seen attached, one before and one behind this tube. The glands seem composed of nucleated cells, imbedded in a granular stroma; and in the concavity of the kidney-shaped organ may be seen a definitely-shaped granular mass leading to the duct, conveying the secretion to the stomach, which it enters just above, or by the side of the insertion of the œsophagus. These glands are evidently salivary or pancreatic, and at least are subservient to the process of digestion.

The stomach (Plate XXXIII. fig. 1 I) itself is a comparatively large and sacculated cavity, of an ovoid shape, the sacculi giving it somewhat the aspect of a bunch of grapes where the berries are closely compacted together. Each little pouch or sacculus has in its centre a large clear nucleus; and on comparing it with the stomach of *Notommata claviculata* (Ehren.), in which hepatic cæca are appended to each sacculus, there is reason to think these nucleated cells also subserve the function of a liver. This belief is further countenanced by the fact of the stomach, when employed in the digestion of the food, assuming a yellowish brown colour, and at least the whole process of *assimilation* is performed in this cavity alone. There is no other orifice to the stomach except the cardiac or œsophageal one; hence there is no intestine, and the siliceous shells of its prey, and other rejectamenta, are brought back to the pharynx and rejected by the oral orifice. In this process also we see the forcipated jaws frequently assisting to eject the larger portions of the digested food. I have frequently seen this act performed, and the empty shells of Brachioni and Closteria returned and forced out again by the action of the jaws. There are apparently long ribbon-shaped muscles (Plate XXXIII. fig. 6) that pass from the pharynx along the œso-

phagus and embrace on many sides the stomach to its very fundus, where they meet and interlace. These muscles not only approximate the stomach to the pharynx, but compress it also, enabling it to discharge the debris of the food. Two or three fine filamentous muscles are attached to the fundus and fixed to the lowest part of the tegumentary case of the animal, serving to retract the stomach again when it has discharged its contents. The principal food appears to be species of Gonium, and other small infusoria; but also at times it will swallow hard and thorny Brachioni, and even the young of its own species. The total absence of all intestinal canal separates this animal from Notommata, which has a distinct gut and cloaca, as is well observed in the *N. claviculata*; and if development of digestive apparatus be taken as a distinctive character, it removes this form to a lower grade than any rotiferous animal I am yet acquainted with.

As it is clear that the growth and nutrition of the animal must proceed from the digestion of appropriate food, and as there is no true vascular system, it follows that the assimilated fluid must permeate the parietes of the stomach and enter the general or peritoneal cavity of the animal, which, however transparent the whole of the body appears to be, must be filled with this colourless nutrient fluid or blood.

In this animal, as well as in the Notommata figured by Ehrenberg, there is a peculiar organ, which in the explanation of figure 2 of plate 49, he designates "kiemen" or gills, and as "kiemengefässe," "gill-vessels thicker than the gill, for which reason the tremulously moving gill cannot be a heart."

This peculiar organ consists in a double series of transparent filaments (Plate XXXIII. fig. 1 K) (for there is no proof of their being tubes or vessels) arranged from above downwards in a curved or semicircular form, symmetrical when viewed in front; or when seen in profile (the most common position of the animal under the microscope) as two series of filaments whose convexity is turned towards the exterior of the body. These filaments above and below are interlaced, loop-like, while another fine filament (Plate XXXIII. fig. 1 L) passes in a straight line, like the chord of an arc, uniting the two looped extremities. To this delicate filament are attached little tags, or appendices, whose free extremities are directed towards the interior of the animal, and which are observed to be affected by a tremulous, apparently spiral motion, like the twisting of a screw. This is undoubtedly due to cilia arranged round these minute appendices.

The tags (Plate XXXIII. fig. 7 B) above described are from eight, twelve, or even twenty in number, varying in different specimens, though always present in greater or less numbers. There seems to be much obscurity in Ehrenberg's description, and he does not appear to be quite decided as to their proper function; for though the designation of kiemen or gills would infer that he supposed them subservient to the purpose of respiration, other observers have suspected them to belong to a cardiac system. Now it does not appear consistent with the class of animals to which these infusoria belong, to expect tubular vessels or a heart, but nevertheless I believe the organs in question to be a peculiar circulating system.

I have said that the body of the animal is filled with fluid, most probably analogous to blood, while the ciliated tags, or appendices, in perpetual motion, must produce currents in this fluid, and probably in an uniform and determinate direction. In this way the nutrient plasma will be brought regularly in contact with all parts of the interior of the body, and the process of nutrition go on as in insects, without the intervention of tubular vessels, the dorsal heart in them serving only to give direction and circulation to the blood. I am the more impressed with this belief, since these filamentous organs are in close approximation with a large contractile sac, presently to be described, which probably performs a respiratory function.

As, however, this is a much-disputed part of the organization of the family of Hydatineæ, I shall here quote Ehrenberg's own observations upon *Hydatina Senta*, which he takes as the type of the whole family.

"It happened to me in 1832 to obtain a clear view of the vibratory corpuscles which Corti in 1794 saw, and doubtingly considered to be four hearts. I found here eight of these bodies, four on each side in two rows affixed to the *sexual glands*. In other Rotifera I saw many more of the same kind; and in *Notommata Syrinx* and *claviculata*, a larger vessel was attached to the free and separated glands. These vibrating corpuscles are small and pear-shaped, free at one extremity and attached at the other, on all sides like little shaking purses, which either have on them a longer spiral coil, or within them four small separate vibrating folds, which are not under the volition of the animal. One only sees them clearly when the animal is flattened by the superimposition of a very thin light plate of glass, not crushing them. In Hydatina these vibrating valves or folds appear to be placed within the little purses. In *Notommata collaris* I have lately seen something prominent on their edges, and must therefore believe these folds to be placed on the outside. Besides, there appears in the neck of Hydatina to be present an opening in direct and important connexion with these organs, that in many other Rotifera projects as a spur-shaped horn. Close round this opening are placed the nerve-loops of the neck, and a nerve-ring appears to encircle it as a ganglion.

"The animalcule appears to take in, and expel alternately, clear water through this opening in the neck, and thus each vibrating organ throughout may be an internal gill producing respiration, although a circulation of the nutrient fluid (säfte), partly on account of the extremely small diameters of the vessels, and partly from the transparency and minuteness of the blood-corpuscles, remains as yet undiscovered, though probably not deficient. Many of the older, as well as more recent observers, who speak of a heart in Rotifera, mistook the pharynx for this organ. Corti took the moving jaws and gills for it; moreover, while no true heart has been discovered hitherto, it is impossible that it should hereafter be found to exist, especially as no congenerous animalcules have one, although by the tremulous motions of the vascular partitions (*gefässwände*) the circulation of the blood is carried on."—Ehrenberg, page 415, fol. edit. 1838.

Besides this development of his views, it will be found that the great naturalist, in the explanation of the plate illustrating the anatomy of *Hydatina Senta*, believed the cords to which the gills or vibratory corpuscles are attached to be male organs, "testiculi" (*männliche drüsen*); a position most unlikely for the location of respiratory organs, were they even probably such. As it will be proved that in the animalcule I am describing no such male organ exists under this form, and that another apparatus appears to subserve the office of respiration, it is far more probable that they are part of the mechanism of circulation, and, as such, secondary to the function of respiration.

It has been previously stated that a valvular opening exists in the inferior part of the animal that gives exit to the matured embryo or to ova, and may therefore, from its obvious and demonstrable purpose, be denominated the vaginal aperture. This communicates with a membranous, highly extensible and very contractile ovisac (Plate XXXIII. fig. 1 P), in which the fœtus is matured, and by the contractions of which it is finally expelled from the mother.

Just above the ovisac, and communicating with the vaginal canal, is a considerable transparent sac (Plate XXXIII. fig. 1 N), which, when distended, presents a spherical shape. It is exceedingly delicate, and may be seen to contract by the action of slender muscular fibres with great rapidity, in which act it is thrown into numerous regular folds or pouches, and in that condition appears not very dissimilar to the large cellular lungs of Batrachia. These contractions and subsequent dilatations go on with some approach to regularity, and I have counted from six to eight in a minute; but when the animal is disturbed, or attempting to escape from the pressure of the "live cage," or in the act of expelling an embryo, the contractions and dilatations of the sac are greatly and irregularly increased, sometimes to twenty in the minute. It is on the outside and over this sac that the principal ciliated tags of the circulatory organ are placed. The explanation which I venture to give is, that this sac draws in the water in which the animal lives, and expels it again by the vaginal orifice, and it is by bringing the blood by means of the ciliary movements of the little bodies just described into intermediate contact with the air of the water, the fine membrane of the contractile sac alone intervening, that aëration or respiration is performed. An analogous contractile sac may be seen in *Rotifer vulgaris*, situated near the cloacal orifice.

At first sight this pulmonary sac (Plate XXXIII. fig. 7 C) appears to be an appendage to the ovisac (Plate XXXIII. fig. 7 D), but frequent observation of the female in all stages of gestation convince me that it has no relation to the generative function. The same sac is described by Ehrenberg, in the explanation to the figure of *Notommata Myrmeleo*, as a contractile *male* vesicle with evident vascular ramification. The position and the description of a contractile bladder show that the learned Professor is speaking of the same organ I have described, but it will be clearly shown by and by that it has no concern with sex, while the vascular ramifications are neither more nor less than the muscular fibrillæ by which the contractions are effected.

Every animal, however low in the scale of beings, is nourished by some process of converting either animal or vegetable products into themselves; but when we observe such elaborate organs of alimentation in Notommata, such as those of prehension, mastication, deglutition and digestion, we may infer at least the existence of some apparatus that may suffice to circulate and aërate the elaborated fluid or blood. A process of respiration is equally important to these beings as food and digestion, for it is well known that the higher forms of infusory animals will not exist in water either deprived of air or in which the air has been consumed by long inhabitation. The contractions of the vesicle I have described resemble very closely the expirations of a vesicular lung, and in some forms of Rotifera it appears almost wholly to vanish when contracted, and by expansion again to become suddenly apparent.

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With regard to the nervous system, traces of such an apparatus may be distinctly recognised in the optic lobe or mass of ganglionic matter, on the centre of which is placed the pink pigmentous matter constituting the organ of vision (Plate XXXIII. fig. 1 C); from this nervous mass a fine filament may be observed passing obliquely down the body of the animal, attached at about the centre of the outer tegumentary case, Plate XXXIII. fig. 1 T. At this point exist two small tubercles, around which are set three or four short hairs, cilia, or setæ. The filament connecting these tubercles with the optic lobe, is enlarged at its lower part by the addition of two or three small ganglionic globules (Plate XXXIII. fig. 7 E), and appears to send off delicate filaments to the stomach, salivary glands, ovaries and ovisac. It may be a question also whether the curved and looped fibres connected with the circulatory organ may not have ganglionic corpuscles intermingled with them.

The muscular system is best explained by reference to the drawing, Plate XXXIII. fig. 8. It is merely necessary to remark here, that besides the long ribbon-shaped muscles that serve to contract and to retract the head and body, there are numerous muscular filaments having their fixed points in the integumentary case, and inserted into the various internal organs upon which they act; thus, there are delicate muscles attached to the fundus of the stomach to retract it into its situation after it has been drawn up to the pharynx either to receive or reject its food.

Other muscles are fixed to the ovaries; and a very intricate set of reticular fibres are expanded over both the respiratory sac and ovisac, producing in the one case the strong expiratory contractions of this vesicle, and in the other the expulsatory action attending the birth of the embryo.

The broad ribbon-shaped muscles have faint indications of cross markings, as seen in the voluntary muscles of higher animals, and in young specimens have frequently still remaining the nuclei of the cells imbedded in the fibre, whence this tissue has been originally developed.

The other more conspicuous organs visible within the transparent body of this animalcule are those appropriated to the reproduction of the species, and are very perfect in their kind.

It may be stated, *in limine*, that it is now certain that these animals are divided into female and male, the latter being one of the most curious organisms I am acquainted with.

As however the general description has hitherto been taken from the female, I shall describe the reproductive organs in them first.

There is an ovary, ovisac, expulsory mechanism, vaginal canal and vulva.

The ovary (Plate XXXIII. fig. 1 O) consists of an elongated mass, curved into the general form of a horseshoe, either extremity being rounded and slightly enlarged. In texture it appears gelatinous, with numerous interspersed granules, forming a stroma, in which are imbedded many nucleated cells (Plate XXXIII. fig. 1) that afterwards become ova. The ovary is larger in proportion as the animal is young, and visibly shrinks and becomes almost atrophied as it is advanced in age and has produced many embryos. This ovary, like the stomach, is very moveable in the general cavity of the body, but in the newly-born female, before many movements have taken place, and especially before the stomach has been distended with food, its position is such that the two horns are pointed upwards, and the digestive sac is placed within the concavity of the horseshoe (Plate XXXIII. fig. 2 O O) : thus the ovary is symmetrically placed, and appears like a double organ united by a broad bridge in the centre. To either horn are attached slender muscles or tegumentary fibres that retain it in its general position, although either producing or permitting free movements; for when the ovisac becomes distended with one or more embryos, which always occupy the lower part of the animal, it, as well as the stomach, is pushed out of its ordinary or original position.

To the lower part of the ovary appears, connected by slight muscular or ligamentous fasciculi, the extremity of the ovisac, which, if unoccupied by an embryo, is closely contracted, and appears like a wavy, extremely delicate membrane. The female is both oviparous and ovo-viviparous, the latter condition being the one most frequently observed; and in fine hot weather it is not unusual to find females with four or five young in various stages of development, from the early ovum to the mature embryo, ready for expulsion.

The extreme transparency of the animal permits the ready observation of all stages of development. We can trace the germinal vesicle, surrounded by a gelatinous and granular mass or yelk, and enveloped in a delicate chorion, still attached to the ovary. The germinal vesicle is generally very distinct and excentric (Plate XXXIV. fig. 2), the whole egg being an ovoid figure. The ovum is then enveloped by the open end of the ovisac, and the base of attachment to the ovary being gradually narrowed to a small peduncle, it finally escapes free into the membranous ovisac, where the further development is carried on. We then shortly observe the ovum to increase in size, the distinct and dark granules appearing to become surrounded with cell-walls, and the gelatinous mass is converted into a large number of distinct nucleated cells, Plate XXXIV. fig. 3. I cannot say I have traced the division of the original cell into two, four, eight, &c. in

arithmetical progression, though this is not improbable, since in an early ovum I have once observed the separation into two distinct portions, in each of which there were several large granules or oil-globules, Plate XXXIV. fig. 5^{a}.

Each granular point, however, seems subsequently to become the nucleus of a cell, round which the wall is developed. After a short time the numerous cells assume a more definite arrangement (Plate XXXIV. fig. 4), and are grouped together in masses, at which time, from the slight irregularities in their contour, the fine chorion is seen around them, forming an envelope for the whole.

By and by the groups of cells become more distinct masses, and a larger collection of them at one end of the ovum (Plate XXXIV. fig. 5) indicates the future position of the head; while smaller subdivisions are symmetrically arranged around another group, which finally becomes the stomach.

Soon after this period, the cells, or groups of them, evidently become developed into tissues, and the embryo begins to assume a definite shape, and the outline of the tegumentary covering is visible. Presently a slight ciliary movement is observed at one end, indicating the head of the animal, and the chorion shortly after bursting, the embryo becomes free, although closely surrounded by the delicate contractile membrane of the ovisac.

Having arrived at this epoch (Plate XXXIV. fig. 10 A), the perfection of the organs rapidly takes place, and we begin to recognise the stomach, salivary glands, ovary, and the ribbon-shaped muscles of voluntary motion; in these latter the original nucleus of the cell, which has elongated and been developed into muscular tissue, is still plainly visible, imbedded, as it were, in the fibre. The embryo has now voluntary motion, for while rapid ciliary movements are constantly going on around the head, the animal frequently contracts and extends its body, rolls over, or changes its position in the ovisac. The jaws may now be seen, and are not unfrequently moved as if exercising or trying their power. The red eye has previously been visible, and now and then the head of the animal is so placed that we are enabled to look down upon it, and observe the symmetrical position of the jaws with the eye placed opposite to the entrance of the mouth and pharynx, a position it is difficult to meet with for any continued period in the adult, from its instability and frequent movements under the glass.

The embryo may now be said to be ready to quit the parent, but some time previous to its exit it is seen exercising various and energetic movements, attempting as it were to escape; but until the valvular opening of the vagina is opened or retracted by special muscles, the forward movements of the fœtus only press the valve closer down, and shuts it more firmly against the side.

At length, after one or two partial openings of the valve, the muscles withdraw it completely, and the ovisac contracting energetically at the same moment, the embryo is suddenly and forcibly expelled into the surrounding water. No sooner however does it escape than it begins to swim about with the peculiar semicircular movements

of the parent, and a few moments after is actively engaged in searching for its food.

Such is the most common form of reproduction; but towards the latter end of the season, the females are found with a totally different form of ovum within them, Plate XXXIV. fig. 9. This ovum is spherical and dark, the outer covering appearing to consist of an aggregation of cells whose rounded form may best be seen at the circumference, where they appear clear and semi-transparent. Beneath this external layer is a second stratum of cells containing pigmentary molecules, that obscure the view of the yelk within, although there may be faintly seen four or five larger cells, with so highly a refracting outline as to give them much the appearance at least of oil-globules, Plate XXXIV. fig. 6. As the ovum becomes a little further advanced the peripheral cells are expanded, slightly club-shaped and striated, giving the whole ovum the aspect of a dark spherical body regularly covered with fine striæ (Plate XXXIV. fig. 7), radiating from a centre: from the want of general transparency no distinct germinal vesicle can be seen.

I have not had sufficient opportunities to trace the further development of these ova, but Mr. Brightwell of Norwich, an excellent and most accurate observer, has watched them for some months after their expulsion from the parent, without observing any further change. These ova are however so totally distinct in their physiological relations to the production of the embryo from the germinal vesicle of the ovum lying naked in the ovisac, that I think it probable they are destined to remain through the winter undeveloped, until the following year, as it will be seen that the period of the summer, during which this animalcule is found, is unusually short, as compared with the date of existence of congenerous species.

A third appearance (or description of ovum) is met with in the ovisac of the parent female. We observe an embryo developed gradually from a germinal vesicle, until it begins to assume a definite shape and independent movement, when we are at once struck with the great difference of its form, size and organization. This is the male, and as it is in itself most curious, and as I believe up to this time quite new and unique, it will require special description.

This male (Plate XXXIV. fig. 11) is about three-fifths the size of the female, generally resembling it in shape, but more flattened at the lower part or fundus, and more prolonged at the side corresponding to the vaginal opening in the female, and which in the male presents a similar valvular opening though comparatively smaller in extent, Plate XXXIV. fig. 12 E. Within this valve is observed a short canal leading to a large spherical bag (Plate XXXIV. fig. 12 G), which may be distinctly seen filled with molecular bodies in constant tremulous movement. From this sac, which I shall denominate the sperm-bag, a short but thick rounded body (Plate XXXIV. fig. 12 F) projects into the canal before mentioned as leading to the lateral opening, and around the extremity of this projecting process, and even within it to a short distance, is a visible ciliary motion indicating a canal (Plate XXXIV. fig. 14 C): on the neck of the

sperm-bag is a fasciculus of muscular fibres (Plate XXXIV. fig. 14 B) which are inserted along the commencement of this evident *penis*, and over the latter organ the membranous sheath is reflected. Muscular bands arising from the tegumentary parietes of the animal, in the vicinity of the valvular opening, go to be inserted into the root of the penis (Plate XXXIV. fig. 14 A A), and may be frequently observed drawing it up to the opening, and even extending it beyond the body of the animal. Muscles also for the purpose of opening the valve (Plate XXXIV. fig. 14 E E), very similar to those for the same purpose in the female, and the bands which bring the penis forward, clearly show it to be an extrusory organ, and form a complete male apparatus.

The sperm-bag evidently contains active spermatozoa (Plate XXXIV. fig. 13), having an oval flattened body (of a high refracting power), and a caudal appendage, that, while in the sac, is in constant vibratile movement; they are somewhat larger than, and of the same general form as, human spermatozoa.

I myself have never observed any action beyond the extrusion of the penis, but my friend Mr. BRIGHTWELL has observed in seven different instances the direct copulation of the two sexes. The following quotation from his notice of the fact in the Annals of Natural History for September 1848, clearly demonstrates this important circumstance.

"*Observations as to the Union between the Sexes.*

"June 15th.—Placed a male and six females in a small glass trough by themselves, and two males and about thirty females in a large trough.

"June 16th, between 7 and 8 A.M.—On examining the small trough observed that the male on approaching one of the females attached himself to its side by the spermatozoid projection, and remained so attached from twenty to thirty seconds. The same male acted precisely in the same manner with four other females. These five connexions took place in about fifteen minutes.

"At 5 P.M.—Saw one of the males in the larger trough attach himself to a young one of the other sex for about twenty seconds, and afterwards to a full-grown female for a somewhat longer time. Saw this last connexion in a clear light most distinctly. The end of the sperm-tube was attached to the side of the female, and the rest of the body of the male was quite free. Saw the same male soon after fix itself by its head to the glass and remain so for thirty seconds, and during this time it continued puffing out and drawing in the sides of its body as if to give them their utmost dilatation.

"June 20th, 5 P.M.—Placed a young female and a male in a trough by themselves and watched them very frequently till eleven at night, and though they came very near each other no conjunction took place.

"June 21st, 8 A.M.—Found the female dead and the male alive. Put three other females to this male, and in a few minutes saw the male as soon as he approached one of the females attach his sperm-tube to its side and remain so attached fifty

seconds. Soon afterwards he attached himself to another very young female and remained so attached seventy seconds. Could discern this latter connexion of the end of the sperm-tube with the side of the female very distinctly.

"4 P.M.—Saw in the trough, by the aid of the microscope with a one-inch achromatic object-glass, a conjunction of a male with a female. On approaching the female the male attached himself by the sperm-tube to her side, and remained so attached nearly a minute. Saw this most clearly, but owing to the movement of the animals in the water it is almost impossible to see more than that there is a distinct adhesion.

"Most of the above observations were made with a single lens only, of two inches focus, and the others with the microscope."

So acute an observer as Mr. BRIGHTWELL could not possibly have been mistaken in the fact so repeatedly observed, and it leaves us therefore in no doubt as to the diœcious character of this singular family; but there is another circumstance connected with the anatomy of the male, so curious as possibly to be unique. The male I have said possesses the same general figure as the female, it has also the contractile vesicle, which I have ventured to name the respiratory sac (Plate XXXIV. fig. 12 D C), as well as the fibres furnished with the vibratory or ciliated tags, subservient to the office of a circulation. It has also the ordinary rotiferous apparatus at the head, through the agency of which its various movements of locomotion are performed; the pink eye (Plate XXXIV. fig. 12 B) is distinct. *It has however no mandibles, no pharynx, œsophagus, pancreatic glands or stomach*; there appear to be no organs of prehension, deglutition, digestion or assimilation. At the lower part of the animal, on the other side of, and opposite to the valvular opening, are three small oval bodies (Plate XXXIV. fig. 12 H), massed together, having no communications by tube or otherwise, but fixed in their place by short ligaments, that may be rudiments of a stomach.

They are not testes, for they have no communications with the sperm-bag, and they do not exist in the female. I have therefore provisionally regarded them as the rudiments of a digestive apparatus.

The difference of sex in these two forms is plainly evidenced by the fact, not only of the difference of structure, the presence of active spermatozoa in the male, but by the observed fact of the intromission of the male organ into the vaginal canal of the female. That the male animal is produced by the female and developed within the ovisac in the same manner as the female embryo, is also proved by many observations; and one of the drawings of the male has been made from a specimen still in the interior of the parent, and even at that period having its sperm-bag filled with active spermatozoa.

Thus this animal is not androgynous, and a careful reconsideration of the whole family of Hydatina is desirable to determine whether this law prevails in this extensive group of infusory animalcules. Had the male not been traced *ab ovo*, or had it been met with apart from female specimens in the water, it had been taken for a

wholly distinct species, and I can easily imagine the males of other species may so far differ in size and apparent organization, as to have been mistaken for distinct races, and their physiological position overlooked.

The absence of all organs for the sustentation of life by food leads to the belief that it is created for a single purpose, and that its duration or term of existence is very short. In this respect it somewhat resembles the drone or male bee, whose utility seems confined to the impregnation of the perfect female or queen. The short existence of this male is further proved by the fact that it is impossible to keep these animals alive for any extended space, and the observer who has not frequent access to the natural pools in which they exist, is dependent for subjects of experiment on their occasional production by the females in the water wherein they are confined.

That a single impregnation is sufficient for the production of many young, is proved by the female continuing to breed in water in which no male can be discovered; but young females so produced will not go on to develope others unless a male be born amongst them.

In what light then are we to look upon an animal wanting those organs, that in the most elementary beings appear to constitute the almost entire structure having a single function to discharge, that of continuing the species, which once effected, it perishes? Such indeed appears to be the case, and is another of those marvellous instances of endless variety in the accomplishment of a particular object by the Creator, in which His works abound.

A few words are necessary as to the habitat of this curious animal. It was first discovered by Mr. Brightwell in 1841, in a pit immediately without the city of Norwich. For a long time it was met with in no other locality, although constant search was made for it in localities likely to abound in Infusoria. Even in this particular pond in some summers no specimens have been detected, while in others it has swarmed in June, July and August. It has however this year been discovered by Mr. King of Norwich in a pool on Mousehold Heath, within a short distance of the same city. I have for many years been accustomed to search the pits and ditches in the neighbourhood of London, and although almost every genus described by Ehrenberg has furnished some species, and abundance of Notommata, especially at Hillingdon near Uxbridge, there have been seen no specimens of this curious animal until by chance I detected it in August of the present year in a pond in Warwickshire, not far from Leamington. As however infusorial animalcules have a very wide range, it is to be hoped it will hereafter be more extensively met with than hitherto, and more especially as from its exquisite transparency and the perfection of its ovaries and ovisacs, as well as from the discovery of a separate male, the process of development can be so easily watched and traced from its earliest commencement. As far as has been hitherto observed, the development of the ovum, through all the phases of germinal vesicle, granular nuclei, nucleated cell, and the conversion of cell into tissue, appears to follow the same type as has been so well described by Burdach,

Von Baer, Von Siebold, Bischoff, Barry and a host of others. The rapidity of the processes, as well as the great clearness with which the changes can be seen, are very favourable for observation; while the viviparous nature of the animal assimilates the conditions more to that of higher organizations, than where development takes place in a true egg expelled from the body of the mother, and dependent upon its own *vis insita* alone.

Explanation of the Plates.

PLATE XXXIII.

Fig. 1. Exhibits the animalcule, of which the preceding pages are a description, seen in the position most generally observed, viz. in profile.

A. The ciliated coronet that surrounds the head.
B. The mouth or anterior aperture.
C. The pink eye.
D. The ganglionic mass on which the eye is placed.
E. The jaws or mandibles.
F. The pharyngeal cavity.
G. The œsophagus.
H. Salivary or pancreatic glands.
I. The stomach.
K. The circulatory apparatus.
L. The ciliated tags appended thereto.
M. Muscles.
N. Contractile or pulmonary sac.
O. Ovary.
P. Ovisac surrounding.
Q. An embryo.
R. Circular bands on the integument.
S. Vaginal or posterior orifice.
T. Lateral aperture, ciliated or setaceous.

Fig. 2. Represents the animalcule seen frontwise or on the abdominal aspect; organs symmetrically placed.

A. The axis of the jaws.
B B. Muscles moving the rami of the jaws.
C. The pharynx.
D. The œsophagus.
E. Salivary glands.
F. Circulatory apparatus, with

G G. Ciliated or vibratile tags.
H. Semilunar slit of the vaginal orifice.
I. Internal valve of vagina.
K. Ovisac.
L. Contractile vesicle.
O O. Ovary.

Fig. 3. The forcipated jaws.
A. The axis.
B. The short ramus.
C C. Processes for the attachment of muscles.
E. Joint.
F. Long ramus of the jaws.
G. Lateral tooth or hook.
H. External or second slender forceps.
I. Sharp or hooked extremity of jaw.
K. Flat or chisel-shaped tooth.

Fig. 4. Represents the oral apparatus seen by looking directly down upon the head. The forcipated jaws are symmetrically placed, surrounded by powerful masses of muscles, and situated above the pharyngeal cavity. The pink eye is seen in front of the jaws and somewhat to one side, overlooking the entrance into the pharynx.

Fig. 5. A salivary gland, highly magnified, 650 diameters.
The gland shows the secreting cells with their central nuclei dispersed in a granular stroma while around what appears to be a duct, entering the œsophagus immediately above the stomach; the cells appear to give place to a delicate granular structure, which may indicate the resolution of the cells into the secreted matter.

Fig. 6. Represents the multilocular stomach, with the œsophagus and salivary or pancreatic glands attached.
Each loculus of the stomach has a clear nucleus on its centre, and while the whole cavity is a digestive sac, it is not improbable the loculi and their nuclei represent rudimentary hepatic cæca.
Within the stomach are seen a Closterium and a Gonium on which the animalcule has fed.
Muscular fibres may be seen passing over the stomach sunk in the depressions between the sacculi of the organ; and attached to the fundus are slender muscles, which are also fixed to the lowest part of the tegumentary case of the animalcule, and serve to retract the stomach after displacement and regurgitation of the digested food.

Fig. 7. Shows a female animalcule, for the purpose of representing more distinctly the circulatory organs (A), with their attached ciliated or vibratile tags (B),

and the contractile vesicle or respiratory bag (C). Both it and the ovisac (D) appear to communicate with the valvular opening or vagina (E), but whether by a separate or common passage is as yet doubtful. The ovisac is partially contracted and thrown into folds, and attached by muscular or ligamentous bands to the yoke-shaped ovary (F). The stomach (G) is displaced to one side.

Fig. 8. Represents the muscular system and what appears to be a rudimentary nervous system.

The muscular bands which retract the body of the animalcule are seen rising by broad origins from the firm coronet of the animalcule, and pass down the interior of the body, free and unattached, to be inserted by digitated processes into those circular tegumentary rings which have been described as vessels by Ehrenberg.

Over the stomach, which is here represented empty and somewhat flattened, muscular bands may be seen extending from the œsophagus to its very fundus. Two delicate muscular bands are fixed to the interior or bottom of the tegumentary case, and inserted into the fundus of the stomach, and are retractors of this organ.

A. Shows the pink eye situated in a mass of nervous or ganglionic matter, from which proceeds a delicate chord, having at B two ganglionic corpuscles and terminating at the two setaceous tubercles at the side of the animalcule at E. At C, delicate nervous chords go off to be distributed to the stomach, pancreatic or salivary glands and ovaries; and at D, another ganglion appears to give off fibrillæ too doubtful to be here indicated.

PLATE XXXIV.

Fig. 1. A portion (one horn) of an ovary, magnified 700 diameters, showing the granular stroma, and the vesicles and their included nuclei and bright nucleoli.

Fig. 2. An ovum, as yet attached to the ovary, exhibiting the granular yelk, and the excentric germinal vesicle, with a bright nucleus.

Fig. 3. The resolution of the yelk into several cells, each having a nucleus.

Fig. 4. A further development of nucleated cells, beginning to be massed together in groups.

Fig. 5. Symmetrical arrangement of the groups of cells, the uppermost group indicating the future position of the head.

Fig 5″. A condition of the ovum seen once only, in which the yelk appears divided into two masses, without regular nucleated cells: a few oil-globules are seen irregularly distributed. Whether this be a fertile ovum is doubtful, but further changes were not observed, the parent animalcule dying.

Figs. 6, 7, 8, 8″ and 9, represent the ova in shelly cases, supposed to be ova that persist unhatched during the winter, or at least which are not developed within the body of the parent female.

Fig. 6. The early stage of the ovum, through the coriaceous coat of which are seen numerous oil-globules in the yelk; the ovum is, however, too opake to permit the germinal vesicle to be seen.

Fig. 7. Further advancement of the ovum, in which a peculiar striated appearance of the flattened cells, which constitute the outer covering, may be observed.

Fig. 8. A similar ovum, and fig. 8″, a portion of these flattened cells, more highly magnified, to show to what is due the peculiar striated appearance.

Fig. 9. An ovum ready to be expelled, in which the dark pigment has been added, which obscures all appearance of cells except at the margin.

Fig. 10. Represents the impregnated female and the development of the ova, those destined to evolve living embryos.

In this figure the ovisac contains four ova in different stages of maturity, viz. one (A) situated at the most inferior part of the animalcule, already nearly developed, in which the various internal organs are seen almost perfected; cell nuclei are still visible in the two long muscles of the body, and as the embryo is seen frontwise, the organs are observed symmetrically placed.

Immediately above this embryo is a second (B) obliquely situated, with the head downwards, and partially obscured by an ovum (C) lying over it, which has proceeded only as far as the conversion of the granular yelk into nucleated cells; while above this is a fourth (D) still attached to the ovary, in which the germinal vesicle is very obvious and excentrically placed.

Fig. 11. Represents the male animalcule in which the various organs are distinctly expressed. This specimen was found swimming free in water, taken from a pond in Warwickshire in August 1848. The spermatozoa are distinctly seen in the sperm-bag.

Fig. 12. A male animalcule drawn from a specimen still in the ovisac of the female.

A. The ciliated coronet.
B. The pink eye.
C. The circulatory organs with their ciliated tags.
D. Contractile or pulmonary sac.
E. The lateral opening, through which
F. The penis, or male extrusory organ, is projected.
G. The sperm-bag filled with spermatozoa.
H. The glandiform bodies, or rudimentary structures, uses at present unascertained.

Fig 13. Spermatozoa from the sperm-bag, obtained by compression.

Fig. 14. Exhibits the organs of generation.

A A. Muscles which extrude the penis.

B. Fasciculus of muscular fibres, which arising from the neck of the sperm-bag are inserted on the body of the penis and expel the spermatozoa. "Ejaculatores seminis."

C. Preputial sheath, within which is seen a ciliary movement.

D. Epithelium lining the sperm-bag, seen by gently expressing the spermatozoa.

E. Muscles which open the external valve or lateral opening through which the penis passes.

XIX. *On the Motion of Gases.*—Part II.

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All experiments on the velocity with which different gases rush into a vacuum, or pass under pressure through an aperture in a thin plate, are in strict accordance with the physical law that the times of passage for equal volumes are proportional to the square roots of the densities of the various gases. Besides being the law of "Effusion," this is also the law of the Diffusion of one gas into an atmosphere of another gas. The result in both cases is simply and exclusively a consequence of specific gravity.

The velocity with which gases of different nature pass through a tube is necessarily much influenced by the law of their effusion, when the tube is short and approaches in character to an aperture in a thin plate. But if the length of the tube is progressively increased, its diameter or the aperture remaining constant, then while the resistance increases and the passage for all gases becomes greatly slower, the velocities of the different gases are found rapidly to diverge from those of their effusion. The velocities of different gases appear at last however to attain a particular ratio with a certain length of tube and resistance; and preserve the same relation to each other for greater lengths and resistances. After attaining this constant ratio, the passage of all the gases becomes slower, exactly in proportion to the increased length of the tube, that is, in proportion to the resistance. The different gases are now equally affected by the resistance, and their relative velocities are therefore undisturbed and remain constant. The effect of the law of effusion upon the velocities is no longer sensible, and appears to be eliminated.

As the rates of passage of different gases through a tube appear to depend upon a new and peculiar property of gases, I have spoken of it as the Transpiration or Transpirability of gases. The rates of transpiration appear not to be affected by the material of the tube, as they are found the same for capillary tubes of glass and of copper and for a porous mass of stucco. I may add that such experiments exhibit a constancy and possess a neatness and precision which is very extraordinary. The experiments of M. Poiseuille indicate an equally remarkable constancy and pre-

cision of result in the passage of Liquids through capillary tubes, which has been fully confirmed by M. Regnault*.

The experiments of my former paper afford good grounds for assuming the existence of a relation in the transpirability of different gases, of an equally simple nature as that which is recognised among the specific gravities of gases, or even as the still more simple ratios of their combining volumes. Compared with solids and liquids, matter in the form of gas is susceptible of small variation in physical properties, and exhibits only a few grand features. These differences of property which are preserved amidst the prevailing uniformity of gases, may well be supposed to be among the most deep-seated and fundamental in their nature with which matter is endowed. It was under such impressions that I have devoted an amount of time and attention to the determination of this class of numerical constants, which might otherwise appear disproportionate to their value and the importance of the subject. As the results, too, were entirely novel, and wholly unprovided for in the received view of the gaseous constitution, of which indeed they prove the incompleteness, it was the more necessary to verify every fact with the greatest care.

Perhaps the most general and simple result which I can offer is, that the transpiration velocity of hydrogen is exactly double that of nitrogen. These gases it will be remembered have a less simple relation in density, namely 1 to 14. This was the conclusion respecting the transpiration of these gases in my former paper, and I have obtained since much new evidence in its favour. The transpirability of carbonic oxide, like the specific gravity of that gas, appears also to be identical with that of nitrogen.

The result which I would place next in point of accuracy and importance is, that the transpiration velocity of oxygen is related to that of nitrogen in the inverse ratio of the densities of these gases, that is as 14 to 16. In equal times it is not equal volumes but equal weights of these two gases that are transpired; the more heavy gas being more slowly transpired in proportion to its greater density. Mixtures of oxygen and nitrogen have the mean velocity of these two gases, and hence the time of air is also found to be proportional to its density when compared with the time of oxygen.

The relation between nitrogen and oxygen is, I believe, equally precise as that between nitrogen and hydrogen. The densities calculated from the atomic weights of oxygen and nitrogen, namely, 16 and 14, being 1 for oxygen, 0·9010 for air and 0·8750 for nitrogen; the observed times of transpiration of equal volumes of the same gases are for oxygen 1, air 0·8970 to 0·9010, and for nitrogen from 0·8680 to 0·8708.

These slight deviations I look upon as of the same character as those which accurate determinations of the densities of the same gases indicate from their calculated or theoretical density; the observed densities of air and nitrogen being 0·9038 and

* Rapport sur un Mémoire de M. le Docteur Poiseuille, ayant pour titre, "Recherches expérimentales sur le mouvement des liquides dans les tubes des très-petits diamètres." Annales de Chimie et de Physique, 3me série, t. vii. p. 50.

0·8785 referred to oxygen as unity (Regnault), instead of 0·9010 and 0·8750; or the observed difference in density is sensibly less than it should be by theory. The departure from the law in the transpiration of the same gases is certainly somewhat wider, and it is in the opposite direction; the difference in the observed times of transpiration being greater instead of less than the calculated times.

The points respecting transpiration which still most demand consideration are the following:—

1. Determination of the resistance and of the dimensions of the capillary at which the transpiration of gases becomes normal; and the properties of serviceable capillary tubes.

2. New determinations of the transpiration of various gases and vapours.

3. Influence of change of density and elasticity, produced by change of pressure, upon transpiration.

4. Influence of temperature upon transpiration.

I. CAPILLARY TUBES FOR TRANSPIRATION.

The transpiration of some gases appears to become sooner normal than others, that is, in capillary tubes which are less elongated or less contracted than is necessary for other gases. This was first observed on breaking down and using portions of the glass capillary tube, H of my former paper, which was comparatively wide, being about 0·0222 inch, or $\frac{1}{45}$th of an inch in diameter, with the great original length of 22 feet; when it allowed 1 cubic inch of air to pass under the pressure of one atmosphere into a vacuum in 15·64 seconds, or it discharged 3·84 cubic inches of air per minute.

The following table exhibits the times of transpiration of equal volumes of several gases by this capillary reduced in length to a little under 20 feet. The table contains two series of experiments. The first is the transpiration time of a constant volume of the gases drawn from a globular vessel standing over water, into a sustained vacuum. This vessel was terminated above and below by glass tubes, forming hollow axes to the globe. The measure transpired was the capacity of the vessel between a mark on the lower and a mark on the upper tube, and amounted to 56·5 cubic inches. The second series, which consists of carbonic acid gas, with air for comparison, is the transpiration of these gases into a nine-pint jar or receiver upon the plate of an air-pump, beginning the experiment with an exhaustion of 28·5 inches by the attached barometer, and terminating at 23·5 inches. It was necessary to measure the volume of carbonic acid in this manner after transpiration and not before it, to avoid the error which the solution of a portion of this gas in water might introduce. The gases all passed through a drying tube containing asbestos moistened with oil of vitriol, before reaching the capillary.

TABLE I.—Transpiration by Capillary H 237·875 inches in length, and $\frac{1}{75}$ inch in diameter.

Gas transpired.	Experiment I.	Experiment II.	Mean.	Air = 1.	Oxygen = 1.	Observations.
Oxygen	1146″	1147″	1146·5	.....	1·0000	Bar. 29·696. Temp. 67° FAHR.
Air	1032	1032	1032·	1·0000	0·9001	
Hydrogen	509	510	509·5	.....	0·4443	
Protocarb. hydrogen (CH_2)	631	630	630·5	.....	0·5499	
Carbonic oxide	994	995	994·5	.....	0·8674	
Air	798	799	798·5	.....	.....	Bar. 29·602. Temp. 69° FAHR.
Carbonic acid	668	668	668·	0·8366	0·7529	

I produce these results principally to show how small the variation is in carefully made experiments, not amounting to more than 1 second in times which exceed 1000 seconds for two of the gases, as well as to afford standard numbers to compare with those obtained for reduced lengths of the same tube.

TABLE II.—Transpiration times of equal volumes by Capillary H of different lengths.

Length of capillary.	Oxygen.	Air.	Carbonic oxide.	Carbonic acid.	Protocarburetted hydrogen.	Hydrogen.
237·875 inches = 1·0000	1	0·9001	0·8674	0·7529	0·5499	0·4443
0·8539	1	0·8983	.....	.....	.....	0·4422
0·6521	1	0·9009	0·8681	0·7585	0·5506	0·4434
0·4513	1	0·9013	0·8743	0·7900	0·5636	0·4424
0·3195	1	0·9131	0·8793	0·8501	0·5826	0·4041
0·2149	1	0·9149	0·8799	0·8849	0·6049	0·3842
0·1234	1	0·9131	0·8790	0·8802	0·5860	0·3924
18·125 inches = 0·0762	1	0·9138	0·8879	1·0395	0·5948	0·3879

The absolute times of transpiration varied with air from 1032 seconds for the greatest to 116 seconds for the shortest length of the capillary.

It will be remarked that the transpiration times of air and hydrogen are preserved with the greatest uniformity, while the length of the capillary is reduced from 1 to 0·4513, air varying only from 0·9001 to 0·9013, and hydrogen from 0·4443 to 0·4424. The variation of the rate of carbonic oxide is more sensible although still small, namely, from 0·8674 to 0·8743. Protocarburetted hydrogen, however, rises for the same change in the tube from 0·5499 to 0·5636, and carbonic acid still more considerably, namely, from 0·7529 to 0·7900. The resistance of the tube is insufficient for shorter lengths, the influence of effusion becoming manifest, and most conspicuously so in carbonic acid. The times of effusion of equal volumes, to which the gases are now converging, although with unequal degrees of rapidity, are, for oxygen 1, air 0·9507, carbonic oxide 0·9356, carbonic acid 1·1760, protocarburetted hydrogen 0·7071, and hydrogen 0·2502.

An important conclusion to be drawn from these results is, that the transpiration of all gases does not become normal for the same length of tube or amount of resistance, but that a greater length of the tube and consequent resistance is more necessary for some than for others. Carbonic acid in particular, of which the effusion rate differs so widely from its transpiration rate, appears to require a considerably greater resistance than the other gases transpired to bring it to a uniform rate. Indeed the results respecting that gas suggest the inquiry whether the resistance is sufficient with the present capillary in its greatest length, and whether the true transpiration time for this gas may not be less than 0·75, the number provisionally adopted. Let us therefore observe the effect of greatly increased resistances upon the transpiration of this and other gases.

A thermometer tube of the finest flat bore was selected, K, of which 52½ inches contained only 13·5 grains of mercury. The bore was not quite uniform, 0·6 grain of mercury occupying 2 inches of the cavity at each end of the tube and 2·3 inches near the middle. Under the pressure of 1 atmosphere, 1 cubic inch of air passed into a vacuum by this capillary in 151·3 seconds, or the discharge of air was not more than 0·4 cubic inch per minute. The resistance was therefore ten times greater than in the capillary H when of its greatest length of 22 feet.

Air and other gases were transpired through K into a two-pint jar placed upon the plate of an air-pump, or into a space amounting to 71·08 cubic inches, till the attached barometer of the air-pump fell from 28·5 to 25·5 inches.

(1.) The time required by air in three experiments was 1075, 1073 and 1074 seconds; and for oxygen in two experiments 1192 and 1192 seconds; the temperature being 56° Fahr. and the height of the barometer 30·162 inches. This gives 0·9010 as the transpiration time of air, referred as usual to the time of oxygen as 1, the result accidentally coinciding with the theoretical number for air.

(2.) The time required by hydrogen in two experiments was 552 and 550 seconds, the time of air being 1081, 1079, 1082 and 1080 seconds; thermometer 57° and barometer 29·918 inches. Dividing the mean number for hydrogen 551 by the mean number for air 1080·5, we obtain 0·5099 as the time of hydrogen, that of air being 1. To reduce the time of hydrogen to that of oxygen as 1, we have to multiply 0·5099 by 0·9010, which gives 0·4593 as the transpiration time of hydrogen. This is a considerable departure from the theoretical number 0·4375; but it was found to be due to a small addition of air to the gas, which it obtained from the water over which it stood in the pneumatic trough, and necessarily much longer than usual, from the slow manner in which it was removed by transpiration through the present capillary. In a series of experiments made with hydrogen containing 1, 2, 4, 25, 50 and 75 parts of oxygen in 100 of the mixture, this capillary was found to give the transpiration times 0·4901, 0·5055, 0·5335, 0·7750, 0·9061 and 0·9718. Half a per cent. of air would therefore more than account for the increased time observed with the first hydrogen. In experiments, also, made with other equally fine capillaries, when the

hydrogen was preserved in a state of great purity by transmitting it by a bent tube from the generating retort to the upper part of the pneumatic receiver, and in large volumes, so that the gas never passed through water, and was retained only a very short time in contact with the surface of that liquid, the transpiration time then fell, as will afterwards appear, quite as low as the theoretical number.

(3.) The transpiration of carbonic oxide took place in 1051 and 1051 seconds, against 1090 and 1089 seconds for air; thermometer 58° Fahr., barometer 29·866. This gives for carbonic oxide the transpiration times 0·9646, air = 1; and 0·8690, oxygen = 1. The transpiration time of the same gas by the former capillary H was 0·8674; while the number corresponding with the theoretical density of the gas is 0·8750.

The capillary K was now shortened to 39·375 inches, and the following experiments were made with it.

(1.) Carbonic acid was transpired in 661 and 659 seconds, thermometer 58°, and barometer 30·024. The time of oxygen was 900 and 903 seconds. The means give 0·7321 as the transpiration time of carbonic acid, a number considerably less than 0·75, and confirming my suspicion that the latter number was too high, and that the resistance of H was not sufficiently great to eliminate the whole influence of effusion in this gas. It may be remarked, in passing, that the new number for carbonic acid approaches 0·7272, which is equal to $\frac{11}{15}$, or is the reciprocal of the density of carbonic acid gas. Such a relation suggests the idea that carbonic acid possesses the time of oxygen, (of which gas, carbonic acid contains its own volume,) diminished by the carbon present, which gives an additional momentum corresponding to its weight to the compound gas, and acts thus entirely in increasing its velocity.

In another series of experiments the numbers were 659 and 659 for carbonic acid, against 900 and 902 for oxygen; thermometer 58°, and barometer 30·052. This gives 0·7303 as the transpiration time of carbonic acid.

(2.) Without entering into a detail of the experiments, I may add, that the capillary K of its present length gave 0·9034 as the transpiration time of air and 0·4500 as the transpiration time of hydrogen; the time of the latter gas being undoubtedly elevated by a minute impurity, as in the former case.

The length of capillary K was now reduced to 26·25 inches, and in order to increase the transpiration time, which fell to about 567 seconds for air, the range of the attached barometer observed was increased from 3 to 5 inches, the observations being made at 28·5 and 23·5 inches of the barometer attached to the air-pump.

(1.) The times for air were 946 and 945 seconds; the time for oxygen 1053 seconds, giving 0·8979 as the transpiration time of air; thermometer 57° and barometer 30·096.

(2.) The times for carbonic acid were 773 and 773 seconds, the times for air observed immediately before being 942 and 943 seconds; thermometer 57° and barometer 29·982. This gives 0·8202 as the transpiration time for carbonic acid referred to air, and 0·7361 referred to oxygen.

The length of the capillary K being now reduced to 13·125 inches, air was found to enter so as to depress the attached barometer from 28·5 to 25·5 inches in 284 seconds, and from 28·5 to 23·5 inches in 472 seconds; thermometer 56° and barometer 29·758 inches. To obtain longer times, the two-pint jar, used as the aspirator-jar, was replaced by the six-pint jar, which last gives an available vacuous space estimated at 201·78 cubic inches. The fall of the attached barometer continued to be observed from 28·5 to 23·5 inches.

(1.) The times of air were 1348 and 1353 seconds; the times of oxygen 1498 and 1499 seconds; thermometer 58° and barometer 29·628. The means give 0·9013 as the transpiration time of air.

Observing only through the smaller range of the attached barometer, namely, from 28·5 to 25·5 inches, the following results were obtained:—

(1.) The time of air was 809, 809 seconds.
(2.) The time of carbonic oxide was 780 and 779 seconds.
(3.) The time of hydrogen was 399, 400 and 398 seconds.
(4.) The time of carbonic acid was 658 and 657 seconds.

The experiments were made successively in the order in which they are stated, with the thermometer at 59° and the barometer from 29·450 to 29·422. The results may be given as follows:—

TABLE III.—Transpiration times.

	Air=1.	Oxygen=1.
Carbonic oxide	0·9635	0·8671
Hydrogen	0·4932	0·4438
Carbonic acid.....	0·8127	0·7314

The transpiration times of the second column are obtained by multiplying the times of the first column by 0·9, a number which represents the time of air with sufficient accuracy, the time of oxygen being 1. It will be observed that the number for carbonic oxide remains wonderfully constant for all lengths of K; that the number for hydrogen 0·4438 now approaches more nearly to 0·4375, probably as nearly as a slight impurity of the gas, resulting from its short contact with water, would admit; and that the number for carbonic acid 0·7314, is still low, and does not differ much from 0·7272.

In a second series of experiments, which need not be detailed, numbers corresponding closely with the preceding were obtained; namely, 0·9003 for air, 0·8656 for carbonic oxide, and 0·7336 for carbonic acid.

The capillary K was reduced to 8·75 inches, or to one-sixth of its original length, the six-pint jar being retained as the aspirator-jar, and the fall of the attached barometer observed from 28·5 to 23·5 inches.

(1.) The times of air were 933 and 933 seconds; of oxygen 1036, 1036 and 1037

seconds; of carbonic oxide 897, 897 seconds; thermometer from 59° to 60°, and barometer from 29·1 to 29·134 inches. These experiments give the following transpiration times:—

Oxygen	1
Air	0·9003
Carbonic oxide	0·8656

(2.) The times of air were 920 and 920 seconds; of hydrogen 450 and 451 seconds; of carbonic acid 763, 762 seconds; thermometer 58°, barometer 29·346. The resulting transpiration times for hydrogen and carbonic acid are 0·4886 and 0·8288, the time of air being 1; or multiplying by 0·9 so as to have oxygen 1—

Hydrogen	0·4398
Carbonic acid	0·7459

(3.) Experiments on the same gases were repeated at a temperature lower by 10° Fahr. The times of air were 902 and 902 seconds; of hydrogen 442 and 444 seconds, and of carbonic acid 742 and 742 seconds; thermometer 48° Fahr., barometer 29·334. These numbers give the transpiration times 1, 0·4911, and 0·8226 for air, hydrogen and carbonic acid respectively; or, with oxygen as 1,—

Hydrogen	0·4419
Carbonic acid	0·7403

Another series of experiments gave for carbonic acid the transpiration time 0·7432 at 43°, and with barometer 29·620. It will be observed that the time for carbonic acid now begins to rise, as if the capillary were too short and the resistance insufficient to neutralize entirely the effect of effusion in that gas. The times however of air, hydrogen and carbonic oxide continue normal.

Experiments were made with the same capillary reduced to 6·4375 inches, or to one-eighth of its original length, which are still pretty normal. The times for air were 670 and 670 seconds; for oxygen 746 and 745 seconds; for hydrogen 322 and 322 seconds; for carbonic acid 563 and 562 seconds, with thermometer from 61° to 62°, and barometer from 29·832 to 29·826. These give the transpiration ratios,—

Oxygen	1
Air	0·8987
Hydrogen	0·4319
Carbonic acid	0·7545

For shorter lengths of the capillary K, the deviation from the transpiration rates becomes very notable. I shall supply the results of such experiments, as they illustrate the progress of the deviation from the transpiration rates in a short and narrow capillary, while the results of Table II. page 352, show the progress of this deviation in a long and comparatively wide capillary.

TABLE IV.—Transpiration times of equal volumes, by Capillary K of reduced lengths.

Length of capillary.	Oxygen.	Air.	Hydrogen.	Carbonic acid.
4·3125 inches.	1	0·8985	0·4250	0·7770
3·25	1	0·9035	0·4176	0·8059
2·1875	1	0·9121	0·3969	0·8446
1·125	1	0·9199	0·3876	0·9379

The absolute times for air, with the tubes of these four different lengths, were 473, 370, 270 and 178 seconds; the temperature varying from 61° to 63°, and the barometer from 29·562 to 29·782 inches. These times, it will be observed, do not become shorter, exactly as the length of the tube is diminished, but less rapidly in a very sensible degree. This is owing to the interference of effusion.

When K was 4·3125 inches in length it allowed 1 cubic inch of air to pass into a vacuum, under the pressure of 1 atmosphere, in 14 seconds; or it discharged 4·3 cubic inches of air per minute. The discharge by the capillary H of its greatest length, 237·875 inches, was 3·84 cubic inches per minute. These two tubes therefore offer a nearly equal resistance to the passage of air under pressure. On comparing the first lines of Tables II. and IV., however, it will be perceived that the transpiration rates of hydrogen and carbonic acid are sensibly more normal for the long than for the short tube, although the difference is not great. Still it appears that contracting the diameter of a tube does not produce an equally available resistance as increasing its length. In other respects the progress of the deviation from the normal transpiration rates of the same gas, and of different gases compared together, in proportion as the resistance diminishes, appears to follow the same law in the short as in the long tube.

While discussing the properties of capillaries of different dimensions, I may allude to results obtained by another capillary M, of the same extreme length, 52·5 inches, and of nearly the same resistance as K, but of which the bore was cylindrical and not flat like that of K. The bore of M was not highly uniform, 0·75 grain of mercury occupying a length of the cavity which varied from 3·3 inches at one end to 2·3 inches at the other end of the tube. It was employed with the two-pint aspirator-jar, and the fall of the attached barometer was observed through the usual range from 28·5 to 23·5 inches.

(1.) This capillary gave the transpiration time of air 0·8997, a highly normal result.

(2.) The times for air in two experiments being 1133 and 1132 seconds, the times of carbonic acid were 913 and 911 seconds; thermometer 68° and barometer 29·672.

Transpiration time of carbonic acid . . . . . 0·7247

In a second series of experiments made upon the same gases, the times of air being 1104 and 1103 seconds, the times of carbonic acid were 892 and 892 seconds; and

of hydrogen 534 and 534 seconds; thermometer 58°·5, barometer 30·068. These observations give the transpiration time 0·7275 for carbonic acid and 0·4355 for hydrogen.

(3.) The times of air being 1109 and 1109 seconds, the times of carbonic oxide were 1070 and 1070 seconds; thermometer 67°·5, barometer 29·808.

Transpiration time of carbonic oxide . . . . . 0·8683

(4.) The times of air being 1098 and 1099 seconds, the times of nitrogen were 1064 and 1062 seconds; thermometer 64° to 65°, barometer 29·904.

Transpiration time of nitrogen . . . . . 0·8708

(5.) The times of air being 1084 and 1084 seconds, the times of hydrogen were 529 and 529 seconds; thermometer 69°, barometer 30·242 inches.

Transpiration time of hydrogen . . . . . 0·4392

In the present experiments with hydrogen, the precautions formerly referred to for excluding as much as possible the access of a sensible trace of air from the water of the pneumatic trough were put in practice. The times obtained for this and all the other gases, with the present capillary, will be observed to be in the highest degree normal.

(6.) The times of air being 1095 and 1096 seconds, those of olefiant gas were 641, 641 and 641 seconds; thermometer 69°, barometer 30·102.

Transpiration time of olefiant gas . . . . . 0·5265

The time formerly obtained for the same gas by the capillary H of small resistance was 0·5186. This new capillary M was afterwards very fully employed in determining the times of various other gases and vapours, and in examining the influence of pressure and temperature. It is therefore desirable to have the preceding results which this capillary gives with the more familiar gases.

(7.) The times of air being 1120 and 1120 seconds, those of protocarburetted hydrogen (the gas of the acetates) were 684, 686 and 685 seconds; thermometer 61°·5, barometer 29·844.

Transpiration time of protocarburetted hydrogen . . . 0·5504

The time 0·5515 was formerly obtained for this gas by capillary E, which was a long tube of small resistance, very like capillary H.

(8.) The times of air being 1110 and 1111 seconds, those of binoxide of nitrogen (NO_2) were 1070, 1070 and 1070 seconds; thermometer 60°·5, barometer 29·948 to 29·782 inches.

Transpiration time of binoxide of nitrogen . . . . . 0·8672

This result is in accordance with the conclusion drawn from my former experiments upon the same gas, made with capillary E, namely, that the time of nitric oxide gas coincides with that of nitrogen and carbonic oxide.

(9.) Observations were made with the same capillary M a little reduced in length, namely, to 50·5 inches, and with a smaller aspirator-jar; the range observed of the attached barometer being still from 28·5 to 23·5 inches.

It now gave for the transpiration time of air 0·8984.

The times for air being 460 and 459 seconds, those of carbonic acid were 381 and 381 seconds, and those of protoxide of nitrogen (NO) 380 and 380 seconds; thermometer 56°, barometer 29·674.

Transpiration time of carbonic acid . . . . . 0·7448

Transpiration time of nitrous oxide . . . . . 0·7429

results which illustrate the identity in transpiration rate of these two gases, which have also the same specific gravity, and appear to correspond remarkably in several other physical properties.

The difference of resistance to the passage of a gas offered by the various capillary tubes already used is certainly considerable; the resistance for equal lengths of tube being in round numbers fifty times greater in the new capillaries K and M, than in the old capillaries E and H. But large as is this range, in which a remarkable uniformity of transpiration rate of the gases has been observed, it may still be much extended. The capillaries of extreme resistance to which I shall now refer, have great advantages over the others already described, and form the instruments which I would recommend for the further study of the laws of transpiration.

A thermometer tube of the finest cylindrical bore being selected, a portion of about 8 inches is taken, and being progressively heated and softened at the lamp, is crushed up into a length of 1 inch or less, which can be done without obliterating the cavity. The cylindrical mass is then, while still soft, drawn out into a tube of ten or twelve times its original length. A thin and extremely fine capillary tube is thus obtained, which is much more regular in bore than might be expected from the description of its preparation. It is convenient to divide the rod, which is less in diameter than a fine straw, into lengths of $4\frac{1}{2}$ inches, and to seal immediately the open extremities of each piece. A transpiration capillary was formed of a bundle of thirty of these little rods, which were placed together within a short glass tube, as a case, of about $3\frac{1}{2}$ inches in length and half an inch in diameter; so that the ends of the rods projected at both ends of the tube. The rods were fixed within the tube by stucco, which was dried and afterwards, while warm, soaked in melted bees'-wax. These arrangements being entirely completed, and the bundle proved to be impervious to air, the ends of the rods were now broken off, and the tubes thus opened. The transpiration instrument P consisted of a bundle of thirty such capillary tubes, each about 4 inches in length. Each end of the solid cylinder was connected with a block-tin tube of the same diameter by means of a thick vulcanized caoutchouc adopter. One of these tin tubes was connected with the aspirator-jar, or left open to the air, and the other connected with the receiver containing the gas to be transpired.

The mode of conducting the experiment was further changed. Instead of drawing the gas through the capillaries into an exhausted receiver or vacuum, the gas was compressed in a stout metallic receiver or condenser, provided with a mercurial pressure gauge, by which the elasticity of the gas within could be observed*. This

* Phil. Trans. 1846, Plate XXXIII. fig. 3.

gauge tube was a barometer about 70 inches in length, with a vacuum above the mercury. The gas was allowed to escape from the condenser through the capillaries into the open atmosphere, or into a space containing air, of which the tension was preserved uniform, and which formed an artificial constant atmosphere, the time being noted which the mercury in the gauge tube of the condenser took to fall through a fixed range of 2, 4 or 10 inches, according to the degree of compression. The available capacity of the condenser was about 72 cubic inches.

The resistance of the fine capillary tube of the present bundle was LOT less than 400 times greater than the resistance of the finest tubes hitherto used, namely K and M, the comparison being made between equal lengths of the different tubes.

Experiments with compound Capillary P.

(1.) Dry oxygen was thrown by a syringe into the condenser till the pressure indicated by the pressure gauge exceeded, by more than 20 inches, the pressure of the external atmosphere. The gas was then allowed to escape from the condenser through the capillaries into the atmosphere, and the times noted which the mercury of the pressure gauge took to fall from 20 to 15, 10, 8, 6, 4 and 2 inches.

TABLE V.—Transpiration of Oxygen.

Pressure by gauge barometer.	Experiment I.	Experiment II.	Experiment III.
inches.	″	″	″
20	0	0	0
15	241	240	241
10	352	353	352
8	202	202	200
6	266	266	265
4	379	382	378
2	653	650	647
From 20 to 2 inches	2093	2093	2083

(2.) A similar series of experiments was made on the transpiration of compressed air, of which the results are as follows:—

TABLE VI.—Transpiration of Air.

Pressure by gauge barometer.	Experiment I.	Experiment II.
inches.	″	″
20	0	0
15	217	217
10	316	316
8	181	181
6	239	238
4	400	400
2	524	524
From 20 to 2 inches	1877	1876

Both these last series and the series which follows on carbonic acid were made

with the thermometer at 66°, and barometer from 30·144 to 30·112 inches. Means were taken to preserve the temperature constant during this and similar experiments, by immersing the condenser, and also the capillary, in vessels of water of which the temperature was watched by an assistant and preserved uniform.

The average times of falling from a pressure of 20 to 10 inches are for oxygen and air, 593 and 533 seconds respectively; numbers which are in the proportion of 1 to 0·8988. The average times from 10 to 6 inches are 467 and 419·5 seconds; that is, as 1 to 0·8983: from 6 to 2 inches, 1030 inches and 924 seconds; that is, as 1 to 0·8971. The average whole time of escape, or during the fall from 20 to 2 inches, is 2088 seconds for oxygen and 1876·5 seconds for air, numbers which are in the proportion of 1 to 0·8987.

The transpiration time of air is therefore highly uniform under different pressures, and approaches closely to its theoretical density or time 0·9010.

(3.) The parallel experiments on compressed carbonic acid gas escaping into air are contained in the following Table:—

TABLE VII.—Transpiration of Carbonic Acid.

Pressure by gauge barometer.	Experiment I.	Experiment II.
inches.	"	"
20	0	0
15	178	178
10	260	260
8	148	148
6	195	195
4	278	279
2	475	474
From 20 to 2 inches	1534	1534

Comparing these times with the times of oxygen, we obtain the following results:—

Transpiration times of Carbonic Acid.

From 20 to 10 inches pressure	0·7384
From 10 to 6 inches pressure	0·7345
From 6 to 2 inches pressure	0·7311
From 20 to 2 inches (average)	0·7346

The times for carbonic acid have not the nearly perfect uniformity of those of air, for different pressures, but still their relation is close, particularly in the lower part of the scale where times are long and can be best observed. The time from 4 to 2 inches is 474·5 seconds with carbonic acid and 650 seconds with oxygen, which give as the transpiration time of carbonic acid 0·7300.

It will be observed how nearly the times for this gas approach 0·7272, the reciprocal of its density.

In a second series of experiments made upon carbonic acid, at the same time as

those which follow upon hydrogen, the transpiration times which were obtained for the three portions of the scale already described were 0·7344, 0·7388 and 0·7294, which approach the speculative number for carbonic acid quite as closely as the experiments previously detailed.

(4.) The hydrogen was prepared (as was always the case) from zinc which contained no arsenic, and was passed through a wash bottle containing oxide of lead dissolved in caustic soda, and dried by passing over asbestos moistened with oil of vitriol. The thermometer was 67° and the barometer 29·506 inches.

Table VIII.—Transpiration of Air and Hydrogen.

Pressure by gauge barometer.	Air.		Hydrogen.	
	Experiment I.	Experiment II.	Experiment I.	Experiment II.
inches.	″	″	″	″
20	0	0	0	0
15	221	221	107	107
10	328	328	158	159
8	188	185	92	91
6	251	251	121	121
4	422	423	176	178
2	579	580	310	308
From 20 to 2 inches.....	1989	1988	964	964

The results calculated from the means of these experiments are as follows, the transpiration time of air being taken as 0·9:—

Transpiration times of Hydrogen.

	Air = 1.	Oxygen = 1.
From 20 to 10 inches ...	0·4845	0·4352
From 10 to 6 inches ...	0·4866	0·4371
From 6 to 2 inches ...	0·4859	0·4364
From 20 to 2 inches ...	0·4867	0·4371

The experimental times for hydrogen vary only in the smallest degree at different pressures, and almost coincide with the theoretical time for this gas, 0·4375, which is one-half of the time of nitrogen and 7-16ths of that of oxygen. This result is so important that I shall make no apology for presenting another series of experiments in which hydrogen was compared directly with oxygen.

The temperature during the following experiments was 67°, and the barometer 29·420 to 29·458 inches.

TABLE IX.—Transpiration of Hydrogen and Oxygen.

Pressure by gauge barometer.	Hydrogen.		Oxygen.	
	Experiment I.	Experiment II.	Experiment I.	Experiment II.
inches.	″	″	″	″
20	0	0	0	0
15	107	107	242	246
10	158	158	263	260
8	91	90	208	208
6	120	120	274	274
4	174	175	396	398
2	298	299	687	687
From 20 to 2 inches	948	949	2170	2173

By dividing the means of the hydrogen numbers by the means of the oxygen numbers, as usual, we obtain the following results:—

Transpiration times of Hydrogen.

From 20 to 10 inches	0·4380
From 10 to 6 inches	0·4367
From 6 to 2 inches	0·4363
From 20 to 2 inches	0·4370

These results are therefore in entire concordance with the preceding series, and with 0·4375 as the transpiration time of hydrogen gas.

(5.) A series of experiments were made on the transpiration of carbonic oxide in conjunction with those last related.

TABLE X.—Transpiration of Carbonic Oxide.

Pressure by gauge barometer above 1 atmosphere.	Experiment I.	Experiment II.
inches.	″	″
20	0	0
15	213	213
10	315	315
8	181	181
6	241	241
4	346	346
From 20 to 4 inches	1296	1296

The experiments on this gas are only given from 20 to 4 inches, some error of observation having occurred in taking the times at 2 inches. Comparing them with the last experiments on oxygen, we obtain the following results:—

Transpiration time of Carbonic Oxide.

From 20 to 10 inches	0·8727
From 10 to 6 inches	0·8755
From 6 to 4 inches	0·8715
From 20 to 4 inches	0·8737

The transpiration time of carbonic oxide thus appears to be uniform at different pressures, and to correspond very closely with its theoretical density, 0·8750. The transpiration times of this gas and of nitrogen no doubt correspond with each other as closely as their densities, and are both double the time of hydrogen.

It thus appears that the results obtained by means of the sheaf of capillaries of extreme resistance are the most uniform of all, and that they afford a confirmation of the conclusions drawn from the results of former capillaries of greatly less resistance, which it is difficult to withstand. These conclusions are, that the times of passage through capillary tubes, of equal volumes of different gases under the same pressure, approximate to, and have their limit in, the following numbers :—

Transpiration times.

Oxygen	1·
Air	0·9010
Nitrogen and carbonic oxide	0·8750
Hydrogen	0·4375
Carbonic acid	0·7272

The times of oxygen, nitrogen, carbonic oxide and air, are directly as their densities, or equal *weights* of these gases pass in equal times. Hydrogen passes in half the time of nitrogen, or twice as rapidly for equal volumes. The result for carbonic acid appears at first anomalous. It is, that the transpiration time of this gas is inversely proportional to its density, when compared with oxygen. It is to be remembered, however, that carbonic acid is a compound gas, containing an equal volume of oxygen. The second constituent carbon which increases the weight of the gas, appears to give additional velocity to the oxygen in the same manner and to the same extent as increased density from pressure, or from cold (as I believe I shall be able to show), increases the transpiration velocity of pure oxygen itself. A result of this kind shows at once the important chemical bearing of gaseous transpirability, and that it emulates a place in science with the doctrines of gaseous densities and combining volumes.

The circumstance that the transpiration time of hydrogen is one-half of that of nitrogen, indicates that the relations of transpirability are even more simple in their expression than the relations of density among gases. In support of the same assertion may be adduced the additional fact, that binoxide of nitrogen, although differing in density, appears to have the same transpiration time as nitrogen. Protoxide of nitrogen and carbonic acid have one transpiration time, so have nitrogen and carbonic oxide, as each pair has a common density.

II. TRANSPIRATION OF VARIOUS GASES AND VAPOURS.

1. *Protocarburetted Hydrogen*, CH_2.

It is necessary to mention how this gas was prepared, as it is one, like olefiant gas, of which we are never quite certain of the absolute purity. Six hundred grains of dried acetate of soda, the same weight of fused hydrate of potash, and nine hundred grains of unslaked quick-lime, all in fine powder, were well-mixed in a coated Florence flask used as a retort, and the gas brought off by heat. The last portions of gas were rejected. The hydrate of baryta never, in my hands, gave so pure a gas, when substituted for the hydrate of potash. Free hydrogen, the usual impurity in this gas, I have formerly shown to have scarcely any effect upon the rate of carburetted hydrogen, when present only to the extent of a few per cent.

The old experiments with the long 20 feet capillaries E and H, of small resistance, agreed remarkably in the transpiration time 0·5515 for this gas. With capillary M, 52·5 inches in length, and transpiring into a vacuum, I obtained 684, 686, 685 seconds as the time for this gas, against 1120 and 1120 seconds for air; thermometer 62°, and barometer 29·844 inches. This gives 0·5504 for carburetted hydrogen for a capillary of great resistance. This gas, in a state of compression, was transpired by the same capillary into air as in the experiments to follow on olefiant gas. The results, without details, were as follows: thermometer 64°, barometer 30·050 to 30·074.

Transpiration of Protocarburetted Hydrogen (into air) by Capillary M, 52·5 inches in length.

	Air = 1.	Oxygen = 1.
From 20 to 10 inches ...	0·6304	0·5495
From 10 to 6 inches ...	0·6254	0·5490
From 6 to 4 inches ...	0·6269	0·5515
From 4 to 2 inches ...	0·6335	0·5525
From 2 to 1 inch	0·6349	0·5607
From 10 to 1 inch	0·6321	0·5541

The transpiration of this gas appears highly uniform at different pressures. Excluding the two observations at the extremes of the scale, the mean result is—

Transpiration time of protocarburetted hydrogen . . . 0·5510.

A repetition of the last experiments gave a slightly different series of numbers, namely, 0·5583, 0·5497, 0·5541, 0·5523, 0·5549; showing that the slight departure from uniformity among the results at different pressures before observed is of an accidental nature, and does not follow any fixed law. The mean of the three preferable new observations gives 0·5510, or precisely the same result as the former series.

This number for protocarburetted hydrogen closely approaches 0·5536, which is seven elevenths, or $\frac{7}{11}$ of 0·870, the time of nitrogen. The numerical relation may be

accidental, but the circumstances that 14, which expresses the density and time of nitrogen, is double the time of hydrogen 7, and that 22 expresses the density of carbonic acid, to which carburetted hydrogen presents a certain chemical analogy in composition, appear to afford some physical basis for it.

The time of protocarburetted hydrogen may also be stated to be one-fourth more than 0·44, the usually observed time of hydrogen itself.

2. *Olefiant Gas.*

The circumstance that olefiant gas has the same theoretical density as nitrogen and carbonic oxide, and yet differs greatly from these gases in transpirability, gives a peculiar interest to the transpiration time of that gas. The olefiant gas used was always prepared in the following manner:—Fifty-four volumes (water ounce measures) of oil of vitriol were mixed with twenty-eight volumes of water and cooled, which gave an acid of specific gravity 1·600. To this twenty-four volumes of alcohol, generally of specific gravity 0·84, were added, and the mixture allowed to stand over night. The gas was evolved by a heat of about 320° Fahr., and transmitted, for the purpose of purifying it through five wash-bottles, the first containing potash, the second water, the third oil of vitriol, the fourth potash, and the fifth oil of vitriol. The process yielded a good deal of ether, with a large product of gas.

My old experiments, with capillary H of great length but small resistance, gave 0·5186 as the transpiration time of this gas. I subsequently obtained the number 0·5241 with capillary K of 8·75 inches in length, and also of small resistance. With capillary M of 52·5 inches in length, and of considerable resistance, I also obtained the number 0·5265; the gas in all these cases passing into the nearly vacuous jar under the pressure of the atmosphere. But the most complete series of experiments was made upon this gas in a compressed state, in the globular digester of 72 cubic inches in capacity, the gas escaping into air. The capillary M was employed of 50·5 inches in length.

Table XI.—Transpiration of Olefiant Gas and Air (into air).

Height of gauge barometer above 1 atmosphere.	Air.		Olefiant gas.	
	Experiment I.	Experiment II.	Experiment I.	Experiment II.
inches.	″	″	″	″
20	0	0	0	0
15	198	196	116	116
10	285	285	165	165
8	161	161	93	93
6	213	213	120	121
4	307	307	174	174
2	530	530	301	301
1	529	530	299	300

The fall from 20 to 10 inches requires 482 seconds in air and 281 in olefiant gas,

numbers which are as 1 to 0·5830. The ratios or transpiration times appear in the following Table :—

Transpiration times of Olefiant Gas.

	Air = 1.	Oxygen = 1.
From 20 to 10 inches ...	0·5830	0·5212
From 10 to 6 inches ...	0·5709	0·5103
From 6 to 4 inches ...	0·5667	0·5066
From 4 to 2 inches ...	0·5679	0·5085
From 2 to 1 inch	0·5656	0·5081

In reducing these results from the scale of air to that of oxygen, the following coefficients were used as the transpiration times of air. They were obtained by experiment. From 20 to 10 inches air = 0·8941 ; from 10 to 6 inches 0·8939 ; from 6 to 4 inches 0·8941 ; from 4 to 2 inches 0·8967 ; from 2 to 1 inch 0·8967 ; the air coefficients being all sensibly lower than 0·9.

The transpiration time of this gas appears to vary at different parts of the scale of pressure fully more than carbonic acid does. This may arise, as with carbonic acid, from the extreme difference which exists between the effusion and transpiration rate of the gas.

Hence an unusually great resistance, which is only met in the lower part of the scale, is required to eliminate completely the influence of effusion upon the transpiration rate. The smallest transpiration time observed above for olefiant gas is 0·5066, which certainly does not differ much from 0·5, or half the time of oxygen. But it would be premature to adopt that relation definitively, as a number nearer to 0·51 would be the more legitimate expression of the whole results.

In a second series of experiments conducted precisely in the same manner, with the thermometer at 67° and the barometer 30·020 to 30·034, the results were as follows :—

Transpiration time of Olefiant Gas (into air).

	Air = 1.	Oxygen = 1.
From 20 to 10 inches ...	0·5855	0·5234
From 8 to 6 inches ...	0·5745	0·5136
From 6 to 4 inches ...	0·5663	0·5062
From 4 to 2 inches ...	0·5642	0·5043
From 2 to 1 inch	0·5647	0·5048
From 20 to 1 inch	0·5669	0·5068

The same remarks apply to the last as to the immediately preceding series of experiments ; the two series agreeing together most closely. The mean of the three times observed in the range of pressure from 6 inches to 1 inch is 0·5051 ; and the least transpiration time observed for olefiant gas (from 4 to 2 inches pressure) is 0·5043.

To contrast the two different methods of transpiration, that of condensed gas escaping into air, and of gas under the usual pressure of the atmosphere only, or under a less pressure, passing into a vacuum, a third series of experiments was made upon olefiant gas. The same globular condenser being full of olefiant gas, of the tension of the atmosphere at the time, which was 30·034 inches, the gas was allowed to escape through the capillary M into the receiver of an air-pump kept vacuous by constant exhaustion. It was thus transpired into a vacuum but with constantly diminishing force, for the force with which the gas was sent out would diminish of course in proportion as the globular receiver was emptied. The barometric gauge tube of this receiver, being closed at top and vacuous, gave the necessary means of observing the progress of the escape of the gas as it was transpired into the vacuum. In the following table of observations, the first column of the height of the gauge barometer is its absolute height, and expresses the whole tension or elasticity of the gas. Thermometer 67°.

TABLE XII.—Transpiration of Olefiant Gas.

Height of gauge barometer.	Olefiant gas.		Air.	
	Experiment I.	Experiment II.	Experiment I.	Experiment II.
inches.				
30	0	0	0	0
25	191	191	327	327
20	276	276	480	480
18	152	152	267	267
16	187	187	316	315
14	242	242	432	430
12	318	319	558	558
10	446	446	773	771
From 20 to 10	1347	1345	2346	2341

The results are sensibly different in one part of the scale from those obtained by the other method of transpiration, as will be seen by comparing the following statement with the former results.

Transpiration of Olefiant Gas (into a vacuum).

	Air = 1.	Oxygen = 1.
From 30 to 20 inches ...	0·5791	0·5212
From 20 to 16 inches ...	0·5476	0·4928
From 16 to 14 inches ...	0·5615	0·5054
From 14 to 12 inches ...	0·5717	0·5145
From 12 to 10 inches ...	0·5777	0·5199
From 30 to 10 inches ...	0·5743	0·5169

The time seems to increase as we descend in the scale, or with the resistance, with the exception of the first observation, which probably is made to deviate from the general progression by some accidental cause. It would probably be more cor-

rect to take the first and second times together, or the whole fall from 30 to 16 inches, which gives—

	Air = 1.	Oxygen = 1.
Transpiration time of olefiant gas.....	0·5659	0·5093

The times from 30 to 14 inches, 0·5093 and 0·5054, will thus closely approach to the average time obtained by the other method. But under 14 inches of pressure, where the transpiration becomes extremely slow as the resistance is greatly increased, the times rise to 0·5145 and 0·5199. In the present state of our knowledge respecting transpiration, it is difficult to decide upon the comparative value of these results, and to say which represents best the true transpiration time of olefiant gas. An unexplained variation of 1½ per cent. in the transpiration time of this gas must at present be admitted, which is a much greater latitude in the results than was observed with nitrogen, hydrogen, protocarburetted hydrogen, or even with carbonic acid.

3. *Ammonia.*

This gas is supposed to have certain chemical relations to olefiant gas, although differing very widely from the latter in its physical properties. The theoretical density of ammonia is 8·5, that of oxygen being 16; or 539·6 to oxygen 1000. It is therefore considerably lighter than olefiant gas; it is also liquefied by pressure, and highly soluble in water, which the latter is not.

This gas was always dried by passing over fragments of fused hydrate of potash. The mode of operating with gases like ammonia, which cannot be retained over water, found most convenient was to maintain a continued and copious evolution of the gas during the whole period of the transpiration experiments, conveying the gas into an empty bottle in the first instance, of which the cork was perforated by three tubes. By one of these tubes the gas entered this bottle, by another the portion of gas required for transpiration was conducted to the capillary, and the third, which was bent downwards and its extremity allowed to dip a line or two into a little cup of water, formed a waste-pipe or relief tube, by which the excess of gas evolved escaped into the atmosphere. The same method was equally applicable to hydrogen, carbonic acid, chlorine, &c., and does away with the necessity of collecting these gases over water, and so exposing them to contamination.

(1.) This gas was transpired by capillary K, 8·5 inches in length, into the six-pint aspirator-jar upon the plate of the air-pump, through the usual range of 28·5 to 23·5 inches on the gauge barometer; thermometer 54°, barometer 29·772 inches. In two experiments with air the times were 982 and 981 seconds; in three experiments with ammonia 546, 546, and 546 seconds. This gives 0·5563 for the time of ammonia referred to air, or multiplying this number by 0·9 to reduce it to the scale of oxygen = 1, we have,—

Transpiration time of ammonia . . . . . 0·5007

The conclusion suggested by this result, that the transpiration time of ammonia is one-half that of oxygen, is not supported so strongly by capillary tubes of great resistance.

(2.) Experiments were made with capillary M, 52·5 inches in length; thermometer 61°, barometer 29·900 to 29·908 inches. The time of air being 1110, 1111, and 1111 seconds, that of ammonia was 632, 632, and 632 seconds; as 1 to 0·5688. Referred to oxygen, the result becomes—

Transpiration time of ammonia . . . . . 0·5119

A second series of experiments with the same capillary, thermometer 61°·5 and barometer 29·800 to 29·810, gave a very similar result, namely, 1121 and 1123 seconds for air, and 640 and 640 seconds for ammonia; numbers which are as 1 to 0·5704, and give,—

Transpiration time of ammonia . . . . . 0·5134

(3.) A third series of experiments was made upon this gas under pressure in the globular digester, and escaping into air by the sheaf of thirty capillary tubes P. The thermometer was at 60°, and the barometer from 29·888 to 29·918 inches during the experiments.

TABLE XIII.—Transpiration of Ammonia (into air).

Height of gauge barometer above 1 atmosphere.	Air.		Ammonia.	
	Experiment I.	Experiment II.	Experiment I.	Experiment II.
inches.	″	″	″	″
20	0	0	0	0
15	218	217	124	124
10	319	321	182	182
8	186	186	107	106
6	243	243	138	139
4	354	355	201	201
2	621	621	350	357
1	635	645	352	350
From 20 inches to 1	2576	2588	1454	1459

The observation at 1 inch, or even at 2 inches, does not admit of the same precision as in the higher parts of the scale, owing to the slowness with which the mercury descends, leaving a doubtful period of 3 or 4 seconds which the mercury is in passing the mark. The experiments at different parts of the scale, it will be seen, concur in giving nearly the same result, except for the last inch, where this uncertainty appears to have occasioned a sensible error.

Transpiration times of Ammonia at different pressures.

	Air = 1.	Oxygen = 1.
From 20 to 10 inches ...	0·5693	0·5112
From 10 to 6 inches ...	0·5711	0·5128
From 6 to 2 inches ...	0·5684	0·5104
From 2 to 1 inch	0·5484	0·4936

The common multiplier by which the numbers of the oxygen scale have been derived from the air scale is 0·898. Excluding the last result, we have, on the oxygen scale,—

The mean transpiration time of ammonia . . . . . 0·5115

This time for ammonia corresponds very closely with the results previously obtained by the long single capillary M, namely, 0·5119 and 0·5134. The coincidence in the rates of M with those of the compound capillary, for a liquefiable gas like ammonia, is a circumstance of considerable importance, as a large proportion of the experiments which I have to detail on gases of this class were made with the first-named only of these capillaries. The number for ammonia certainly approaches to 0·5076 and 0·5093, the mean transpiration-times of olefiant gas, but cannot be said to coincide with them, and is of course somewhat more distant from 0·5.

4. *Cyanogen.*

This gas was prepared from well-crystallized and perfectly dry cyanide of mercury. To secure its purity the gas was besides passed over red oxide of mercury and chloride of calcium. The gas was conveyed to the capillary in the same manner as ammonia. The capillary employed was the long tube M, of 52·5 inches, the gas under the pressure of the atmosphere being drawn into the two-pint aspirator-jar, exhausted as usual upon the plate of an air-pump. Thermometer 60°, barometer from 29·910 to 29·864 inches.

The experiments were made in the following order:—air, 1113, 1114 seconds; cyanogen, 626, 628, 627 and 627 seconds; air, 1117, 1117 seconds. The slight increase of the air-time in the last-made experiments is undoubtedly owing to the fall of the barometer. The ratio of the cyanogen to the first air-time is 0·5631, and to the second air-time 0·5613; or 0·5068 and 0·5052, with oxygen =1. The mean of the two results gives,—

Transpiration time of cyanogen . . . . . 0·5060

The transpiration time of cyanogen may therefore be confounded with that of olefiant gas, 0·5076, transpired in the same manner, although the densities of these two gases differ so widely as 14 to 26 (oxygen =16).

5. *Hydrocyanic Acid.*

A considerable quantity of the absolute acid was prepared by distilling 15 ounces of crystallized ferrocyanide of potassium with 9 ounces of oil of vitriol diluted by an equal weight of water. The liquid acid was afterwards dried by digesting it over pounded chloride of calcium.

As hydrocyanic acid is liquid at the usual temperature, air or hydrogen saturated with the vapour of the acid was transpired instead of the pure substance itself. The air or hydrogen was made to stream through the liquid acid contained in a wash-bottle to a depth of 2 inches, and surrounded with water to which a slight heat was applied, so as to maintain the water and wash-bottle at the fixed temperature of the

experiment, and to compensate for the cold of evaporation. The tension of the hydrocyanic acid vapour at 59°, the temperature of the experiments, was found to be 18·8 inches. The composition of the mixed vapour operated upon was—

	Volumes.	
Air or hydrogen	10·8	or 36·48
Hydrocyanic acid	18·8	or 63·52
	29·6	100·00

The vapour was transpired under the pressure of the atmosphere by the capillary M, 52·5 inches in length, into the two-pint aspirator-jar, through the usual range (28·5 to 23·5 inches) of the attached barometer. Thermometer 59°, barometer 29·518 to 29·644 inches.

The transpiration time of air was 1138 and 1138 seconds in two experiments. The time of air impregnated with hydrocyanic acid was 807, 809, 808, 808 seconds, in four experiments; which gives to the latter the ratio of 0·7100. Multiplying by 0·9, we obtain—

Transpiration time of air saturated with hydrocyanic acid vapour at 59° 0·6390.

It is obvious therefore that hydrocyanic acid vapour is greatly more transpirable than air. The theoretical density of hydrocyanic acid vapour is 13·5, the density of oxygen being 16.

Hydrogen gas equally impregnated with hydrocyanic acid vapour was transpired in the times 579 and 579 seconds, which gives the ratio to air of 0·5088. Multiplying by 0·9, we obtain—

Transpiration time of hydrogen saturated with hydrocyanic acid vapour at 59°, 0·4579.

Judging from our former results on mixtures of hydrogen with denser gases, in which it appeared that the rate of the mixture never deviated far from that of the dense gas in a state of purity, unless the proportion of hydrogen exceeded 50 per cent, it may be inferred that the transpiration time of pure hydrocyanic acid vapour is between 0·4375, the time of hydrogen, and 0·4579, the observed time, but much nearer to the latter than to the former. For the transpiration of gaseous mixtures of more nearly equal density, it is known, on the contrary, that the transpiration time does not deviate far from the mean time of the constituents when transpired separately. Taking the transpiration time of air as 0·9, and that of hydrocyanic acid vapour as 0·46, then 36·48 volumes of the first and 63·52 volumes of the second would give a mean time of 0·6205.

The time observed of a mixture in these proportions was 0·6390.

Hydrocyanic acid is composed of equal volumes of cyanogen and hydrogen united without condensation. The transpiration time of the compound gas is intermediate between the times of its constituents.

6. *Hydrosulphuric Acid.*

This gas was evolved by the action of hydrochloric acid upon the sulphide of antimony; it was washed with water, and afterwards dried by passing over chloride of calcium.

(1.) Hydrosulphuric acid was first transpired by a short length of capillary M, of 8·75 inches, into the six-pint aspirator-jar, through the usual range of 28·5 to 23·5 inches of the attached barometer: thermometer 62°, barometer 29·674 to 29·652 inches. The following observations were made in the order in which they are related:—times of air, 999 and 1001 seconds; of hydrosulphuric acid, 692, 692 seconds; of hydrosulphuric acid gas saturated with the vapour of bisulphide of carbon, 682, 680 seconds; and lastly, of hydrosulphuric acid again, 685, 685 seconds.

The ratio of the first hydrosulphuric acid to air is 0·691, and of the second 0·685; the ratio of the hydrosulphuric acid saturated with the vapour of bisulphide of carbon is 0·681, or differs little from that of hydrosulphuric acid itself; showing that these two sulphur compounds nearly coincide in transpirability. Multiplying these results by 0·9, we have—

Transpiration time of hydrosulphuric acid (1)	0·6219
Transpiration time of hydrosulphuric acid (2)	0·6165
Mean transpiration time	0·6192

This gas proved less uniform in its rate in different experiments than I have generally observed for other gases, at least with the present capillary.

In a repetition of the preceding experiments, thermometer 60°, barometer 29·860 to 29·858, the times observed were for air, 982, 983 and 981 seconds; for hydrosulphuric acid saturated with bisulphide of carbon, 659, 659, 659 seconds; and for hydrosulphuric acid alone, 663, 664 seconds; which give the ratios to air of 0·6711 and 0·6746. And multiplying by 0·9, we have—

Transpiration time of hydrosulphuric acid	0·6071

(2.) Hydrosulphuric acid gas was also transpired by means of the long capillary M, 52·5 inches in length, into the two-pint aspirator-jar. It was then supplied from a wash-bottle with a relief tube as in the experiments upon cyanogen and ammonia, without being retained over water. Thermometer 59°·5 Fahr., barometer 29·550 to 29·292.

The times of air were 1134, 1134 seconds; of hydrosulphuric acid, 782, 780 seconds; of hydrosulphuric acid carried through a column of bisulphide of carbon 2½ inches in depth and kept at the fixed temperature of 59°·5, 773, 771, 772 seconds. These give the ratios to air, of 0·6887 for hydrosulphuric acid, and 0·6808 for hydrosulphuric acid saturated with the vapour of bisulphide of carbon at 59°·5. Also, multiplying by 0·9,—

Transpiration time of hydrosulphuric acid	0·6198

This last result almost coincides with the first determinations with the short capillary M, namely 0·6192. The mean of the two results is,—

Transpiration time of hydrosulphuric acid . . . . . 0·6195

The mercury in the gauge tube of the air-pump was soiled by these experiments, and the tube required to be cleaned after them.

7. *Bisulphide of Carbon.*

At the temperature of 63°, the tension of the vapour of bisulphide of carbon was observed to be 10·462 inches. Experiments were made with air, oxygen, hydrogen and carbonic acid gases, all saturated with the vapour of bisulphide of carbon at 63° and with barometer from 29·874 to 29·850 inches. The short capillary K, 8·75 inches in length, was made use of, and the gas was transpired into the six-pint aspirator jar. The gases were impregnated by the vapour in passing through a large U-shaped tube filled with cotton-wick which was moistened by the liquid bisulphide of carbon.

Air alone was transpired in 982 and 981 seconds; air saturated with bisulphide of carbon vapour in 837 and 838 seconds; oxygen saturated with bisulphide of carbon vapour in 895 and 896 seconds; hydrogen saturated with bisulphide of carbon vapour in 662 and 661 seconds; carbonic acid saturated with bisulphide of carbon vapour in 763 and 762 seconds. The ratios appear in the following Table:—

Transpiration times of different gases saturated with CS_2 at 63°.

	Air = 1.	Oxygen = 1.
Oxygen	0·9124	0·8212
Air	0·8533	0·7679
Carbonic acid	0·7769	0·6992
Hydrogen	0·6739	0·6065

It may be safely concluded that the transpiration time of bisulphide of carbon is not less than 0·6065, but probably sensibly greater. It must, according to former observations, approach very closely to, if it does not actually coincide with, 0·6195, the transpiration time of hydrosulphuric acid gas.

8. *Sulphurous Acid.*

This gas was evolved by the action of copper upon sulphuric acid, was washed with water, and conveyed in a continuous manner to a bottle with a relief tube from which the capillary was supplied, as in the experiments with ammonia and cyanogen. The gas was dried by passing over pumice soaked in oil of vitriol before reaching the capillary.

(1.) With short capillary K, 8·75 inches in length, the six-pint aspirator-jar, and usual range from 2·85 to 23·5 inches: thermometer 53°, barometer 29·964 to 29·942 inches.

The time of air was 970, 970 seconds; of sulphurous acid, 714 and 711 seconds; ratio of latter to air, 0·7345. Multiplying by 0·9, we obtain—

Transpiration time of sulphurous acid . . . . . 0·6610

(2.) With the long capillary M, 52·5 inches in length, this gas was transpired into the two-pint jar: thermometer 60°·5, barometer 29·880 to 29·878 inches.

The time of air was 1120, 1120 and 1120 seconds; the time of sulphurous acid 814, 811 and 812 seconds. Using the two last observations only for sulphurous acid, we obtain the transpiration time 0·7245 for that gas, air being 1; or multiplying by 0·9,—

Transpiration time of sulphurous acid . . . . . 0·6520

In a second series of experiments with the same capillary, thermometer 58° and barometer from 29·880 to 29·886, the following observations were made. Time of air, 1105, 1111, 1105 and 1111 seconds; time of sulphurous acid, 798, 797 and 798 seconds, and ratio to air 0·7199. This gives—

Transpiration time of sulphurous acid . . . . . 0·6479

The mean of the two results by this capillary gives—

Transpiration time of sulphurous acid . . . . . 0·6500

9. *Sulphuric Acid.*

Both air and oxygen gas saturated with the vapour of anhydrous sulphuric acid were transpired under the pressure of the atmosphere into an air-pump vacuum, by the short capillary K, 8·75 inches in length. Certain new arrangements of the apparatus, however, were required in operating upon so highly corrosive a vapour as that of sulphuric acid. Two ounces of the solid sulphuric acid were melted by heat in a U-tube stuffed with asbestos, and having while liquid impregnated the asbestos, were allowed to cool and become solid again before the air or other gas to be saturated with sulphuric acid vapour was conducted through the U-tube. For the tin conducting tubes of the former arrangements, glass tubes were substituted, and the air-pump was employed to exhaust a stout globular glass globe of six pints in capacity and provided with three openings, which was employed as the aspirator cavity. Two of the openings of the globular receiver were in the sides and one at the bottom of the receiver; by one of the former openings the globular receiver was connected with the transpiring capillary and by the other with the air-pump; a tube containing carbonate of potash being interposed between the receiver and the air-pump, to arrest the acid vapours and prevent them from reaching the air-pump, when the latter was used for exhausting the globular receiver. The third and lower opening communicated with a gauge barometer, by which the tension of the gas or vapour within the globular receiver was observed. The mercury in this barometer was found to adhere slightly to the glass and not to descend with an entirely level surface in the transpiration experiments, owing to a slight chemical action of the acid vapour upon the

mercury. This circumstance prevents the times being observed with the same precision as in other gases.

With the thermometer from 72° to 74°, and barometer from 30·076 to 30·028 inches, the times of descent of the gauge barometer from 28·5 to 23·5 inches were, with air, 865 and 863 seconds; with air saturated with sulphuric acid vapour at 73° Fahr., 960, 961, and 958 seconds. The ratio of the last times to air is 1·1106; and multiplying by 0·9, we obtain,—

Transpiration time of air saturated with vapour of SO_3 at 73° . . 0·9993

The tension of the vapour of anhydrous sulphuric acid at 73° was observed to be 11·50 inches.

The experiments on sulphuric acid vapour were repeated: thermometer 67°·5, barometer 29·914 to 29·908 inches; the range of the gauge barometer now observed, however, being only from 28·5 to 24·5 inches.

The time for air was 695 and 694 seconds; for oxygen saturated with the vapour of sulphuric acid at 67°·5, 786 and 782 seconds; for oxygen alone at 68°, 774 seconds; and for air alone again 692 seconds. The result to be deduced is,—

Transpiration time of oxygen saturated with vapour of SO_3 at 67°·5 . . 1·0130

The sensible equality of the times of air observed at the beginning and end of the experiments proves that the working of the apparatus was not deranged by the sulphuric acid vapour. It is evident that the time of pure sulphuric acid vapour itself cannot deviate far from that of oxygen gas. Sulphuric acid appears to be one of the very few gases, the transpirability of which, if not really coincident with, is slightly inferior to, or slower than, that of oxygen.

10. *Chlorine.*

The transpiration time of chlorine has a peculiar interest as that of an elementary substance. The same arrangements were had recourse to with this corrosive gas as with sulphuric acid. It was found necessary, in addition, to preserve a small column of water above the mercury in the gauge barometer, to defend the metal from the action of the chlorine, or at least to prevent the surface of the metal from becoming foul and adhesive. This gas immediately reached the capillary, like ammonia, from a bottle with a relief tube, to permit the escape of the redundant supply. It was dried by means of chloride of calcium.

(1.) The transpiration was made by capillary K, 8·75 inches in length, into the six-pint globular receiver as aspirator, from 28·5 to 23·5 inches by the gauge barometer attached to the latter: thermometer 70° to 71°, barometer 30·222 to 30·208 inches.

The times of air in two experiments were 865 and 866 seconds; the times of chlorine 670 and 672 seconds; giving the ratio to air of 0·7753. Multiplying the latter number by 0·9, we have—

Transpiration time of chlorine . . . . . 0·6978

(2.) In a second series of experiments with the same capillary, the following

observations were made; the thermometer being 72° to 74°, and barometer 30·248 to 30·218 inches.

The times of air were 858, 860 and 859 seconds; the times of carbonic acid 711 and 712 seconds; the times of chlorine 670, 670, 670 and 670 seconds; the time of air again 866 and 867 seconds. A slight increase in the air-time is observed, after the chlorine experiments, but I would refer this increase more to the rise of two degrees in temperature between the first and last observations, than to any derangement in the apparatus. Taking the last observed air as the standard of comparison for the chlorine, and the first observed air for the carbonic acid, we find—

	Air = 1.	Oxygen = 1.
Transpiration time of chlorine	0·7732	0·6959
Transpiration time of carbonic acid ...	0·8282	0·7454

But the true transpiration time of chlorine gas is probably less than 0·6959, for the true time of carbonic acid is certainly less than 0·7454, the time obtained above for the latter gas. The present capillary, it has been already remarked, is one of too small resistance to bring out the true transpiration time of a gas whose effusion rate differs very widely from its transpiration rate. The present experiment indeed is not inconsistent with the true transpiration time of chlorine, being 2 or 3 per cent. lower than that observed, or falling as low as 0·66, that is, two-thirds of the time of oxygen.

(3.) The transpiration of chlorine was also observed by means of the long capillary M, 52·5 inches in length, with the same six-pint glass globular receiver as aspirator-jar. The fall observed by the gauge barometer was only 3 inches, or from 28·5 to 25·5 inches. Thermometer 58°, barometer 29·742 inches.

The time of air was 1907 and 1911 seconds; of chlorine 1432 and 1395 seconds. The difference of 37 seconds in the two observed times of chlorine, which is so considerable, arose from the action of chlorine upon the mercury; for notwithstanding that the latter was covered with water, its surface became so uneven that the observations could not be made with any great nicety. The first observation of chlorine gives the time of that gas 0·7501 referred to air, and 0·6751 referred to oxygen; the second observation gives the time of chlorine 0·7307 referred to air, and 0·6576 referred to oxygen. Calculating from 1413·5 seconds, the mean of the two observed times for chlorine, we obtain—

	Air = 1.	Oxygen = 1.
Transpiration time of chlorine	0·7404	0·6664

The transpiration time of chlorine appears therefore to be about two-thirds of the time of oxygen; or, chlorine passes through a tube with $1\frac{1}{2}$ time the velocity of oxygen.

11. *Bromine and Hydrochloric Acid.*

The only observations which I possess upon the transpiration of these two substances were made by means of the short capillary K, of 8·75 inches in length, the six-pint globular receiver being the aspirator, and the fall being as usual from 28·5 to 23·5 inches of the gauge barometer. For both the bromine and hydrochloric acid the bottle and relief tube were employed also as before, to regulate the supply of gas to the capillary. Chloride of calcium was employed to dry the gases.

The time of air was 846, 848 seconds; of hydrochloric acid, 693, 693 seconds; of air saturated with the vapour of bromine at 75°, 889, 889 and 889 seconds; of hydrogen saturated with the vapour of bromine, 760, 760 seconds: thermometer from 73° to 75°, barometer 30·230 to 30·178 inches. In an observation which was made at the same time upon the tension of bromine vapour, it was found that liquid bromine placed in an air-pump vacuum depressed the mercurial gauge 9·19 inches at 75°, which may therefore be taken as the tension of the vapour of bromine in the present experiments. The results are as follows:—

	Air = 1.	Oxygen = 1.
Transpiration time of hydrochloric acid gas	0·8181	0·7363
Transpiration time of 9·2 vol. bromine and 21·0 vol. air.....	1·0496	0·9446
Transpiration time of 9·2 vol. bromine and 21·0 vol. hydrogen	0·8973	0·8076

It appears that the transpiration time of hydrochloric acid observed, 0·7363, is greater than that of chlorine, 0·66, while that of hydrocyanic acid was found less, on the contrary, than that of cyanogen.

Bromine vapour increases the transpiration time of air, and is therefore less transpirable. This vapour, however, does not appear to be greatly more transpirable than sulphuric acid vapour or oxygen gas.

12. *Ether* (*Oxide of Ethyl*, $C_4 H_5 O$).

The ether employed was carefully washed with water, to deprive it of alcohol, and afterwards dried by agitation with pounded chloride of calcium. Dry hydrogen and other gases were impregnated with the vapour of this substance in the same manner as with bromine.

(1.) The first experiments were made with the short capillary K, 8·75 inches in length; the gas being transpired as usual under the pressure of the atmosphere into the exhausted six-pint aspirator jar, through the range from 28·5 to 23·5 inches of the gauge barometer of the air-pump: thermometer 56°, barometer 29·670 to 29·708 inches. The tension of the ether vapour at 56° being found 12·85 inches, the mixture transpired may be represented as composed of 12·85 volumes ether vapour and 16·85 volumes gas; or of 43·26 ether vapour and 56·74 gas in 100 volumes.

The time of air was 988, 988 seconds; of hydrogen 474, 473 seconds; of hydrogen gas saturated with ether vapour at 56°, 498, 500 seconds; of oxygen gas saturated with ether vapour at the same temperature, 696 and 695 seconds. The transpiration times deducible from these observations are,—

	Air = 1.	Oxygen = 1.
Transpiration time of hydrogen	0·4792	0·4312
Transpiration time of ether vapour and hydrogen	0·5051	0·4546
Transpiration time of ether vapour and oxygen	0·7040	0·6336

It thus appears that the transpiration time of hydrogen, 0·4312, is only increased to 0·4546 by 43·26 per cent. of ether vapour. As the influence of hydrogen upon the rate of transpiration of the dense gases and vapours is scarcely sensible, this may be held as proving that the time of ether vapour does not sensibly exceed the time of the hydrogen mixture, 0·4546. But as the experiment has been made with a capillary of small resistance, it is not impossible that the normal time of ether vapour may be still sensibly less.

(2.) The capillary M, 52·5 inches in length, with the two-pint aspirator, was now used, the other arrangements remaining as before: thermometer 68°·5 to 69°, barometer 30·242 to 30·264 inches.

The time of air was 1084, 1084 seconds; of air saturated with ether at 68°·5 (59·5 ether vapour to 40·5 air), 675, 676 and 673 seconds; of hydrogen saturated with ether vapour at 68°·5 (59·5 ether vapour to 40·5 hydrogen), 533, 529 and 531 seconds; of oxygen saturated with ether vapour at 68°·5 (59·5 ether vapour to 40·5 oxygen), 728, 725 and 727 seconds; of hydrogen alone, 529, 529 seconds. The tension of ether vapour was observed at the time to be 17·95 inches at 69°. The results deduced from these experiments are as follows:—

	Air = 1.	Oxygen = 1.
Transpiration time of ether vapour and air	0·6224	0·5601
Transpiration time of 59·5 ether vapour and 40·5 hydrogen	0·4898	0·4408
Transpiration time of 59·5 ether vapour and 40·5 oxygen	0·6771	0·6039
Transpiration time of hydrogen	0·4880	0·4392

In this capillary of great resistance, the time of hydrogen is therefore not sensibly affected by nearly one and a half times its volume of ether vapour, from which it may be inferred that the transpiration time of ether vapour itself does not diverge sensibly from that of hydrogen. The near if not perfect coincidence in transpirability in these two substances is very remarkable, considering their great dissimilarity in physical characters, particularly in weight, the densities of hydrogen and ether vapour being as 1 to 37.

Although hydrogen and ether may have the same transpirability, still the influence which each of these gases exerts upon the transpiration of other gases with which it

is mixed, is widely different. It will be seen by the experiments above on ether and air, or ether and oxygen, that the transpiration time inclines most to the ether rate, while in hydrogen mixtures the time also deviates from the mean of the mixed gases, but greatly in the direction of the rate of the other gas, and not towards the hydrogen rate. The density of a gas is no doubt an important element in this influence.

In an experiment with the short capillary K, the time of olefiant gas was reduced from 0·5246 to 0·4816, by saturation with ether vapour at 60°·5.

The rates of hydrogen and ether appear to diverge from each other in experiments made at a high temperature. The water in the copper trough in which the long capillary M was always placed, with the view of commanding a constant temperature, was heated to 203° (95° centig.), and preserved at that temperature during the continuance of the following experiments. Thermometer in air 60°·5, barometer 29·956 to 29·982 inches.

Time of air 1634 and 1637 seconds; of hydrogen, 798 and 797 seconds; of hydrogen saturated with ether vapour at 60°·5, 863, 863 seconds. As the gas transpired was measured at 60°·5 instead of 203°, the temperature at which it passed through the capillary, these times fall to be diminished in the proportion of the volume of air at 203° and at 60°·5 respectively. We thus obtain as the three mean times in which equal volumes were transpired at 203°,—air 1282·4 seconds, hydrogen 625·9 seconds, and hydrogen saturated with ether vapour at 60°·5, 677·3 seconds.

	Air = 1.	Oxygen = 1.
Transpiration time at 203° Fahr. of hydrogen	0·4880	0·4392
Transpiration time at 203° of hydrogen saturated at 60°·5 with ether vapour	0·5281	0·4753

While air and hydrogen preserve, at 203°, their usual ratio of transpirability, ether vapour appears therefore to become sensibly less transpirable at the high temperature.

13. *Methylic Ether* (*Oxide of Methyl*, C_2H_3O).

This vapour was evolved in a continuous manner in proportion as required for transpiration, with the arrangements necessary for gases soluble in water. The vapour was passed over both hydrate of potash and chloride of calcium. The experiments were made with the short capillary K, 8·75 inches in length, like the first experiments with common ether. Thermometer 56°, barometer 29·650.

Time of air 993 and 991 seconds; of methylic ether, 532 and 532 seconds; of methylic ether saturated with the vapour of common ether at 56°, 508, 506 and 507 seconds.

Transpiration times.

	Air = 1.	Oxygen = 1.
Methylic ether	0·5363	0·4826
Methylic ether saturated with ether vapour at 56°	0·5111	0·4600

The time of methylic ether, 0·4826, is decidedly longer than that of common ether, 0·4546, as the latter was formerly observed by the same capillary; and consequently an addition of ether vapour shortens the methylic ether time, as appears in the second experiment, where the transpiration time of such a mixture falls to 0·4600.

14. *Hydrochloric Ether* (*Chloride of Ethyl*, $C_4 H_5 Cl$).

The experiments were made with the same short capillary K, 8·75 inches in length, and with the other arrangements as for the two preceding ethers. Thermometer 56°, barometer from 29·794 to 29·758 inches.

The time of air was 980 and 981 seconds; of hydrochloric ether, 548, 544 and 543 seconds.

	Air = 1.	Oxygen = 1.
Transpiration time of hydrochloric ether.....	0·5543	0·4988

It would be unsafe to draw any conclusion from a single experiment upon this ether and that experiment made with a capillary of inferior resistance, but it may be remarked that the time of this ether approaches to half the time of oxygen, while the density of the vapour is little more than double that of this gas; the theoretical density of hydrochloric ether vapour being 32·25 to hydrogen 1 and oxygen 16.

15. *Hydrochloric Methylic Ether* (*Chloride of Methyl*, $C_2 H_3 Cl$).

This ether, which like the two last is entirely vaporous at the temperature of the experiments, was prepared by distilling together half a pound of wood-spirit, one and a half pounds of oil of vitriol and one pound of common salt. The gas was exposed to a large quantity of dilute caustic soda in two wash-bottles, and dried afterwards by chloride of calcium. The same capillary and arrangements were employed as in the immediately preceding experiments. Thermometer 54°, barometer 29·862 to 29·856 inches.

The time of air was 973, 973 seconds; of chloride of methyl, 592, 587 and 582 seconds; of chloride of methyl again, after changing the solution of caustic soda in the wash-bottles, 592 and 592 seconds. Calculating from the last observed time of chloride of methyl, we have—

	Air = 1.	Oxygen = 1.
Transpiration time of chloride of methyl.....	0·6084	0·5475

It thus appears that the chloride of methyl has a longer time, or is more slowly transpired than the corresponding chloride of ethyl; as the oxide of methyl was also found to be less transpirable than the oxide of ethyl. Indeed the difference between the two oxides and between the two chlorides appears to be the same, or about 0·045

in both cases. This is in accordance with the general observation, that transpiration is promoted by increase of density. The theoretical density of chloride of methyl is 25·25 to hydrogen 1 and oxygen 16.

16. *Water.*

Although great care was always taken to dry air when transpired, as well as other gases, in all experiments, still it does not appear that the rate of air is much affected by the presence of aqueous vapour unless the latter is present in considerable proportion.

The times observed by capillary K, 8·75 inches in length, into a vacuum, were for air dried by chloride of calcium 1008 seconds, and for air drawn afterwards directly from the atmosphere, of which the temperature was 60° and the dew-point 32°, 1006 and 1006 seconds. So small a difference may be due to accidental causes.

With dry air at 60°, the times with the same capillary were, upon another occasion, 1021 and 1021 seconds; and with air of 60° temperature, but containing aqueous vapour with the dew-point at 38°, 1018 and 1017 seconds.

In other experiments, the presence of aqueous vapour appeared to occasion a sensible retardation in the time of air. The transpiration was made into a vacuum by the capillary M, 52·5 inches in length; the temperature of the capillary being maintained at 58°·5, and the barometer varying from 29·798 to 29·832 inches. The air was charged with vapour by passing through a tube filled with cotton wick, which had been previously moistened with dilute sulphuric acid of different strengths. The time of dry air was 1115, 1115 seconds; of air carried over the fourth hydrate of sulphuric acid ($HO.SO_3+3HO$), 1117, 1117 seconds; of air passed over the eighth hydrate ($HO.SO_3+7HO$), 1120 and 1121 seconds; of air passed over the eighteenth hydrate ($HO.SO_3+17HO$), 1122, 1122 and 1121 seconds. Here we observe in the dampest air a slight but sensible increase of the air time, not exceeding 7 seconds. But on repeating the experiment immediately afterwards with dry air, the time was 1120 and 1119 seconds, or within two seconds of the immediately preceding observations with moist air. Indeed the transpiration of moist air appears to produce a slight but sensible retardation of a persistent character, probably from the condensation of a film of moisture on the inner surface of the capillary, which is not immediately removed by the subsequent passage of dry air.

With the same capillary, thermometer 57° and barometer 30·136 to 30·078 inches, dry air was transpired in 1089, 1089 seconds; dry hydrogen in 532 and 532 seconds; air saturated with aqueous vapour at 57°·5 in 1098, 1098 seconds; hydrogen saturated with aqueous vapour at the same temperature, in 548 and 548 seconds; and lastly, dry air, first in 1106 seconds, and afterwards in 1084 and 1085 seconds. Here the damp air is less transpirable, volume for volume, than dry air by 9 seconds. Also, dry air immediately following the damp air does not recover its usual transpirability in the first experiment.

These experiments upon damp and dry air seem to indicate that the transpiration

time of aqueous vapour does not differ greatly from that of air itself. The influence of aqueous vapour upon the time of hydrogen, however, is considerably less than that of air upon the same gas, and therefore suggests a more rapid transpiration.

17. *Alcohol.*

Air was impregnated with the vapour of alcohol of specific gravity 0·835 at 60°, barometer 29·358. The tension of the vapour of alcohol of specific gravity 0·813 at 60° is estimated at 1·23 inch. The capillary K, 8·75 inches in length, was made use of, with an air-pump vacuum, as in all these experiments.

The time of dry air was 1013 and 1014 seconds; of air containing alcohol vapour, 1011 and 1012 seconds. The rate of air is scarcely affected, and consequently the time of alcohol vapour must approximate to that of air.

18. *Naphtha and Coal-gas.*

In experiments made with air saturated with the vapour of coal-tar naphtha at 62°, the capillary K being employed, the times obtained for air alone were 978 and 979 seconds; for air saturated with naphtha vapour, 949 and 949 seconds. The transpiration time of air is diminished 30 seconds, showing that the volatile hydrocarbons of naphtha are highly transpirable, like ether vapour. The time of coal-gas, taken from the service-pipes of a London company, and observed in the same circumstances, was 621 and 622 seconds; of the same coal-gas impregnated with naphtha vapour, 621 and 621 seconds, or the naphtha vapour produced no sensible change in the transpirability of the gas; showing a near coincidence in their transpirabilities. The transpiration time of the coal-gas, reduced to the oxygen scale, is 0·5716, or a little more than protocarburetted hydrogen, 0·5510.

That a considerable quantity of naphtha vapour was taken up by the coal-gas, notwithstanding that its transpiration was unaffected, appears in certain experiments which were made with a particular object upon the effusion of the same gases. The capillary was removed and replaced by a plate of platinum foil, G of former paper, having an extremely minute aperture, the other arrangements remaining the same. The gases were all moistened with water. For the passage of equal volumes into an air-pump vacuum (the six-pint aspirator-jar, through the usual range from 28·5 to 23·5 inches of the attached barometer), the times were, at 61°, for air, 434 and 434 seconds; for hydrogen, 139 and 139 seconds; for coal-gas, 314 and 314 seconds; for coal-gas saturated with naphtha vapour at 61°, 331 and 331 seconds; for hydrogen and naphtha vapour, 194 and 193 seconds; and for air with naphtha vapour, 503 and 503 seconds. It is to be remembered that the densities of the gases effused are in the proportion of the squares of these times, and may be deduced from the latter. The time of coal-gas is increased by the addition of naphtha vapour, but to a much less extent, than hydrogen and air are, no doubt from the former being from the first partially saturated with naphtha vapour.

A good deal of light could be obtained, I believe, upon the composition and value of coal-gas by a combination of effusion and transpiration experiments. Great density, which would be indicated by slow effusion, is always valuable, unless when occasioned by air, carbonic oxide or carbonic acid, which gases exclusively make the transpiration slow; so that slow effusion with rapid transpiration would mark the coal-gas of superior quality.

III. TRANSPIRATION OF AIR OF DIFFERENT DENSITIES OR ELASTICITIES.

A series of observations on air varying in density from 0·5 to 2 atmospheres, made with the long 20-feet capillary E in my former paper, appeared to establish the conclusion that "for equal volumes of air of different densities, the times of transpiration are inversely as the densities." The law of Effusion, or flow of air into a vacuum by an aperture in a plate, is entirely different; equal volumes of air of all densities passing in equal times.

With the short capillary K, 8·75 inches in length, the result was now found to be materially different. Air in three different states of rarefaction was drawn into a sustained vacuum from a globular receiver of which the capacity was 56·5 cubic inches, standing over water. To command the desired density of the air in the globular receiver, the little system of the latter and the basin of water in which it stood was retained within a large air-pump receiver, the atmosphere of which was adjusted to the requisite pressure. Thermometer 62°, external barometer from 29·984 to 29·936 inches.

Transpiration of equal volumes of Air.

Density or elasticity.	Time in seconds.	
	Experiment I.	Experiment II.
1 atmosphere	2172	2173
0·75 atmosphere	2948	2946
0·5 atmosphere	5292	5288

It will be observed that the time 5292 seconds for air of 0·5 density is considerably more than double 2172 seconds, the time for air of 1 density.

With compressed air, varying in density from 1 to 2·5 atmospheres, the deviation from the law was equally conspicuous; the times of transpiration of equal volumes at 1, 1·25, 1·5, 1·75, 2 and 2·5 atmospheres, being in the ratio of 1, 0·8625, 0·7553, 0·6834 and 0·5519, instead of 1, 0·8, 0·6666, 0·5714, 0·5 and 0·4.

On operating, however, with the long capillary M, 52·5 inches in length, and of great resistance, results were again obtained in strict accordance with the law. The air was drawn from a metallic digester provided with a gauge barometer, in which it was preserved of a constant elasticity; this digester itself being supplied from a second similar digester, in which the air was in a state of still higher compression.

The air was transpired into the two-pint aspirator-jar (capacity about 72 cubic inches) upon the plate of the air-pump, for the usual range of the gauge barometer from 28·5 to 23·5 inches. Thermometer 66°, external barometer 30·122 to 30·086 inches.

Transpiration of equal volumes of Air.

Density or elasticity.	Time in seconds.		Reduced time of means.	Calculated or theoretical times.
	Experiment I.	Experiment II.		
1 atmosphere.....	1095	1096	1095·5	1095·5
1·25 atmosphere.....	707	707	883·1	884·8
1·5 atmosphere.....	493	493	739·5	737·3
1·75 atmosphere.....	359	359	628·25	632
2 atmospheres	277	276	553	553
2·25 atmospheres	218	217	489·4	491·5
2·5 atmospheres	176	176	440	442

The column of "Time in seconds" contains the times of the fall of the air-pump barometer from 28·5 to 23·5 inches actually observed, and which are produced by the admission to the aspirator-jar of an equal volume of air of constant density. These times must therefore be multiplied by the density in atmospheres of the air transpired, to obtain the reduced times of the following column. It will be observed that these reduced times are in perfect harmony with the "Calculated times" of the last column. Indeed nothing could illustrate more strongly the great precision of which transpiration experiments are susceptible, than these results.

The conclusion to be drawn from the present observations with the capillary M, and the old observations with E, as compared with the observations made with the short capillary K, is that to bring out the normal effect of densities on transpiration, a greater resistance and length of tube are necessary than are required for the observations of the normal relations in the transpiration times of such gases as oxygen, nitrogen and hydrogen; for the short capillary K, which fails so much in the law of densities, exhibits the other relations nearly with as much accuracy as the long capillary M. The marked superiority also of the 20-feet tube E over the 8-inch tube K, although the power of resistance of these two capillaries is nearly equal, suggests again the idea that resistance produced by elongation of the capillary acts differently from an equal resistance produced by contracting the diameter of the capillary, and more advantageously in transpiration experiments.

IV. TRANSPIRATION OF AIR AND OTHER GASES AT DIFFERENT TEMPERATURES.

The experiments which I have made upon the transpiration of air and also of other gases at different temperatures are very numerous, but not altogether satisfactory. Looking upon the experiments as only preliminary, I shall confine myself at present to a statement of results without detail, and endeavour to return to the subject at some future opportunity.

The transpiration of equal volumes becomes slower as the temperature rises. The experiments which follow upon air, carbonic acid and hydrogen, were made upon different days with slightly different barometric pressures, so that the absolute times of one gas cannot be compared with another; but this is unnecessary for our present purpose. The capillary employed was M, 52·5 inches in length, and of great resistance.

TABLE XIV.—Transpiration of equal volumes at different temperatures.

Temperature.	Time in seconds.		
	Air.	Carbonic acid.	Hydrogen.
32° FAHR.	1054·1	857·9	545·4
59	1092·8	897·4	557·8
86	1133·4	931·5	577·7
113	1175·7	969·4	598·8
140	1211	993·9	615·9

The difference of time of transpiration at the two extreme temperatures, 32° and 140°, is 157·9 seconds for air, 136 seconds for carbonic acid, and 70·5 seconds for hydrogen. The differences, calculated in the proportion of the transpiration times of the same gases at the temperatures usually observed (56° to 74°), namely air 0·9, carbonic acid 0·73, and hydrogen 0·44, are for carbonic acid 128·1 seconds instead of 136, and for hydrogen 73·2 seconds instead of 70·5. It would be unsafe to conclude from these small deviations that the transpiration of the three gases in question is unequally affected by heat in the range of temperature from 32° to 140°; for at temperatures distant from the temperature of the atmosphere, the unavoidable errors of observation increase in magnitude. The increment upon the time of air was 156·2 seconds, and upon hydrogen 62·8 seconds, at 140°, in a repetition of the same experiments.

My most unexceptionable experiments all concur in showing that no sensible change takes place in the transpiration ratios of hydrogen, nitrogen and carbonic oxide, at temperatures so high as 347° FAHR. Thus the observed transpiration times of a mixture of equal volumes of hydrogen and carbonic oxide at 60° and 347°, were 0·8870 and 0·8853; the transpiration times of air observed at the same temperatures being taken as unity. The transpiration times of a mixture of equal volumes of hydrogen and nitrogen, referred to the times of air in the same manner, were at 65°, 0·8939; at 347°, 0·8924; again, at 64°·5, 0·8930; and at 347°, 0·8872. The transpiration ratios are thus as nearly as possible constant at these widely distant temperatures.

The transpiration times of air and hydrogen alone, at 203°, were found on two different occasions as 1 to 0·4841, and 1 to 0·4880. Multiplying these hydrogen times by 0·9 to bring them to the scale of oxygen, we have for the transpiration times of

hydrogen at 203°, 0·4357 and 0·4392, numbers which might have been obtained at atmospheric temperatures.

Carbonic acid, however, appears to present a sensible deviation from this uniformity of rate. In a series of observations made upon this gas at 60°, 203°, 299° and 347°, its transpiration time referred to air at the same temperatures was 0·8291, 0·8551, 0·8777 and 0·8907; and referred to oxygen, 0·7448, 0·7541, 0·7741 and 0·7855. The transpiration time of carbonic acid at 347° varied in other experiments from 0·7729 to 0·7905, the time of oxygen being 1. The protoxide of nitrogen gave the number 0·7969 at the same high temperature.

The time of oxygen appears also to become relatively slower at high temperatures, although much less considerably than carbonic acid. It gave the numbers 0·8877 and 0·8860 for air at 347°, instead of 0·8984, the number at low temperatures. As we may assume from its uniform relation to hydrogen that the nitrogen remains constant, it follows that the oxygen has become relatively slower in transpiration at the high temperature.

If oxygen deviates from a supposed normal rate at high temperatures, it cannot necessarily coincide with that rate at any lower temperature, which is accidental, such as that of the atmosphere. But this influence of heat upon the transpiration time of oxygen is, I believe, still sensible at the low temperature in question.

By increasing the time of oxygen, this influence of heat may be the cause of that slight deviation, so uniform in its amount, of the observed times of air and nitrogen from their theoretical times, which was always remarked. I am disposed then to look upon the slight inconstancy of transpiration rate observed in some gases at different temperatures, as a fact of the same class as the deviations from their theoretical specific gravities observed in a greater or less degree in the same substances, and to those other points in which all the gaseous bodies we have to operate upon depart in some measure from the mechanical idea of a perfect gas.

The normal effect of temperature upon transpiration, as observed in air, varies I find with the resistance of the capillary in a much higher degree than any other property of transpiration; the retardation from the same change of temperature being much greater in a capillary of great than small resistance. The resistance of a capillary such as M, which exhibits so exactly the law of densities, is insufficient to bring out the full effect of temperature. With the fine tubes of the compound capillary, on the other hand, the limit to the retarding influence of heat seems to be reached. The retardation then appears to be simply in proportion to the expansion; and rarefaction by heat, therefore, to have the same effect upon transpiration as expansion from diminished pressure.

In illustration of this inequality of action upon heated air, I may refer to results obtained by two capillary tubes of small and of intermediate resistance, before stating the normal results of capillaries of extreme resistance.

With the copper capillary tube described in my former paper, and which admitted

1 cubic inch of air into a vacuum in 22 seconds, the time of passage of a constant volume of air into a vacuum was 853 seconds at 60°, 899 seconds at 116°, and 924·5 seconds at 152°. The theoretical times, or those corresponding to the rarefaction by heat at these temperatures, are 853, 945 and 1004 seconds. Here the observed times at 116° and 152°, are 46 and 79·5 seconds shorter respectively than the times obtained by calculation; and the difference in transpirability observed at the high and low temperatures only amounts to about one-half of what it should be.

With capillary M, of which the resistance is seven times greater than the last capillary, the observed times of air at 59° (15° centig.), and at 203° (95° centig.), were 1106·5 and 1286·4 seconds. The time at the higher temperature is 1400 seconds by calculation, and the observed time is therefore 113·6 seconds deficient. The difference at the high and low temperatures amounts to nearly two-thirds of the difference which theory requires. The deviation is therefore less than with the preceding capillary.

Air compressed in the globular digester with pressure gauge, of which the capacity was reduced to about 10 cubic inches by the introduction of mercury, was transpired by a small capillary V, 3 inches in length, into the atmosphere, from a pressure beginning at 17 inches above that of the barometer. Thermometer 50°, barometer 29·546 to 29·590.

The resistance of this capillary is excessive. Under a pressure of 17 inches of mercury, 1 cubic inch of air is transpired in 2329 seconds, or the volume transpired is 0·0258 cubic inch per minute.

TABLE XV.—Transpiration of air under pressure (into air) at different temperatures.

Pressure by gauge barometer.	Time in seconds.		Ratio at 203°, Time at 50° = 1.
	Thermometer 50° FAHR.	Thermometer 203° FAHR.	
17 inches.	0″	0″	
16	1370	2329	1·7000
15	1445	2442	1·6900
14	1541	2601	1·6880
From 17 to 14 inches.....	4356	7372	1·6924

Now the volume of air at 32° being =1, at 50° it is 1·0366, and at 203°, 1·3480. But it must be remembered that the volume actually transpired in the experiment was greater at 203° than that at 50°, in proportion as the volume of air is expanded at the higher of these two temperatures, that is as 1·3480 to 1·0366 (volume at 32° = 1). It is therefore necessary to reduce the observed times of the table at 203° in that proportion. The time from 17 inches to 16 is thus reduced from 2329 to 1792·5 seconds, which last is the true time of the passage of the same volume at 203° as passed at 50°. The law requires that the times of equal volumes should be inversely as the densities of air at these temperatures, or as 1·0366 to 1·3480. Thus calculated from

1370 seconds, the time at 50°, the time at 203° is 1780·9 seconds; the time actually observed was 1792·5 or 11·6 seconds more, a close approximation considering the difficulties of the experiment.

But the resistance does not require to be so excessive as in capillary V to bring out the law of temperature. It appeared equally distinct in a capillary tube, having only one-ninth of the resistance of V for equal lengths. This tube however was used in lengths of 4½ inches (instead of 3 inches), so that its resistance is properly stated at one-sixth of V. A sheaf was put together of thirty lengths of the new tube, forming the compound capillary Q. The digester was employed of its full capacity, of 72 cubic inches, to contain the compressed air, which was allowed to escape by the channels of Q into the atmosphere. The range of pressure was from 20 inches to 8. The observed times at 49° and 203° without reduction were 802, 799 and 798 seconds at the low temperature, and 1350 and 1347 seconds at the high temperature. Taking the means 800 and 1349 seconds and reducing as in the experiments with V, we have 1036·1 seconds for the high temperature. Now the calculated time for that temperature is 1041·6 seconds, or only 5·5 seconds above the observed time. The barometer during these experiments marked from 30·044 to 30·058 inches.

In another series of experiments, the time observed at 49° being 797 seconds, the times observed after reduction, at certain intermediate temperatures, were as follows:—

TABLE XVI.—Times of transpiration of Air (into air) in seconds.

Temperature.	Observed time.	Calculated time.	Error of observation.
49° FAHR.	797	797	
96	879·3	870·4	+ 8·9
141	950·1	935·8	+14·3
203	1020·8	1032·1	−11·3

The deviations of the observed from the calculated times, from 8·9 to 14·3 seconds, are small considering the difficulty of maintaining the temperature constant in the experiments. Nor are they always in the same direction. This appears in a third series of experiments, conducted in the same manner as the last, of which I subjoin the results.

TABLE XVII.—Times of transpiration of Air (into air) in seconds.

Temperature.	Observed time.	Calculated time.	Error of observation.
49° FAHR.	797	797	
96	897·3	870·4	+8·9
141	932·3	940·8	−8·5

These observations leave little doubt that the transpiration of air at different temperatures takes place according to the law by which the times above have been cal-

culated. In one experiment which was made upon oxygen at 49° and 203°, the increase upon the time at the higher temperature corresponded within 0·7 per cent. of the increase upon the time of air, and evidently followed the same ratio. I may add that the transpiration times of air and oxygen, as determined by a single observation in each case, were 0·9058 to 1 for the compound capillary Q, and 0·9020 to 1 for the single capillary V of extreme resistance.

In conclusion I may sum up the general results hitherto obtained in this inquiry.

1. The velocities with which different gases pass through capillary tubes bear a constant relation to each other, and appear to constitute a peculiar and fundamental property of the gaseous form of matter, which I have termed transpirability. The constancy of these relations, or of the transpiration times, has been observed for several of the gases for tube resistances varying in amount from 1 to 1000. These relations, there is reason to believe, are more simple in their expression than the densities of the gases. The following relations are particularly remarkable.

The velocity of hydrogen is exactly double that of nitrogen and carbonic oxide.

The velocities of nitrogen and oxygen are inversely as the specific gravities of these gases.

The velocity of binoxide of nitrogen is the same as that of nitrogen and carbonic oxide.

The velocities of carbonic acid and protoxide of nitrogen are equal, and directly proportional to their specific gravities, when compared with oxygen.

The velocity of protocarburetted hydrogen is 0·8, that of hydrogen being 1.

The velocity of chlorine appears to be $1\frac{1}{2}$ that of oxygen; of bromine vapour and sulphuric acid vapour the same as that of oxygen.

Ether vapour appears to have the same velocity as hydrogen gas.

Olefiant gas, ammonia and cyanogen to have equal or nearly equal velocities, which approach closely to double the velocity of oxygen.

Hydrosulphuric acid gas and bisulphide of carbon vapour appear to have equal or nearly equal velocities.

The compounds of methyl appear to have a less velocity than the corresponding compounds of ethyl, but to be connected by a certain constant relation.

2. The resistance of a capillary tube of uniform bore to the passage of any gas is directly proportional to the length of the tube.

3. The velocity of passage of equal volumes of air of the same temperature but of different densities or elasticities, is directly proportional to the density.

4. Rarefaction by heat has a similar and precisely equal effect in diminishing the velocity of the transpiration of equal volumes of air, as the loss of density and elasticity by diminished pressure has.

5. A greater resistance in the capillary is required to bring out the third result, or the law of densities, than appears necessary for the first and second results; and a

resistance still further increased, and the highest of all, to bring out the fourth result or the law of temperatures.

6. Finally, it will be remarked throughout, that transpiration is promoted by density, and equally whether the increased density is due to compression, to cold, or to the addition of an element in combination, as the velocity of oxygen is increased, by combining it with carbon without change of volume, in carbonic acid gas.

It was no part of my plan to investigate the passage of gases through tubes of great diameter, and to solve pneumatic problems of actual occurrence, such as those offered in the distribution of coal-gas by pipes. But I may state that the results must be similar, with truly elastic gases such as air and carburetted hydrogen, whether the tubes are capillary or many inches in diameter, provided the length of the tube is not less than 4000 times its diameter, as in the long glass capillaries of my early experiments. The small propulsive pressure applied to coal-gas is also favourable to transpiration, as well as the great length of the mains; and I should therefore expect the distribution of coal-gas in cities to exemplify approximately the laws of gaseous transpiration. The velocity of coal-gas should be 1·575, that of air being 1, under the same pressure (p. 383). And with a constant propulsive pressure in the gasometer, the flow of gas should increase in volume with a rise of the barometer or with a fall in temperature, directly in proportion to the increase of its density from either of these causes.

XX. *Examination of the proximate Principles of some of the Lichens.*—Part II.

By John Stenhouse, *F.R.S.*

Received February 14,—Read March 29, 1849.

*Gyrophora pustulata**.

THIS lichen has been long employed in the manufacture of archil, though the quantity of colouring matter contained in it is by no means considerable, being little more than a twelfth of that in the *Roccella Montagnei*.

The *Gyrophora pustulata* is the Tripe de Roche of the Canadian hunters, who, notwithstanding its disagreeably bitter taste, occasionally use it as an article of food in seasons of scarcity. A memorable instance of this occurred in the case of Messrs. Franklin and Richardson, who during their disastrous journey to the shores of the Polar sea, after the failure of their supplies, subsisted almost entirely upon this lichen during several weeks. The *Gyrophora pustulata*, on which I operated, was brought from Norway, where it is annually collected in considerable quantity for the manufacture of archil. The colouring principle was extracted by maceration with milk of lime, and was precipitated in a gelatinous state by neutralizing the lime solution by muriatic acid, precisely in the way so frequently described in the first part of this paper. I may mention however that the most convenient mode of effecting this operation on a considerable scale, is to steep the lichens, previously cut into small pieces, for some hours in water till they are thoroughly soaked. They should then be stratified with a great excess of slacked lime in a large barrel furnished with a false bottom pierced with small holes, under which a spigot is placed; in fact, in exactly such an arrangement as is employed by the soap-makers for preparing caustic lyes. Water is then poured into the top of the barrel, and when it has remained on the mixture of the lime and the lichens for an hour or so, it is drawn off by opening the spigot, when the solution runs off quite clear of a deep brownish colour. Water is still added in successive quantities so long as the lime solution, when neutralized by muriatic acid, continues to afford a precipitate. The great advantage of this arrangement is, that it can be easily and rapidly executed on a large scale, and that the extraction and filtration are effected by a single operation.

The gelatinous precipitate from the lichen, which had a reddish brown colour after being washed with cold water by decantation to remove adhering muriatic acid, was collected on a cloth filter and dried by a very gentle heat. When the greater portion

* I am indebted to the kindness of John King, Esq., of George M'Intosh and Coy, chemical manufacturers, Glasgow, for the lichens employed in this part of the investigation.

of the moisture it contained had been removed, it was found advisable to treat it for a short time with a small quantity of dilute spirits of wine at nearly a boiling temperature. This had the effect of freeing it from a greenish-coloured resinous substance. The undissolved portion of the precipitate, which had now become much whiter, was next digested with strong alcohol and a considerable quantity of purified animal charcoal, great care however being taken to prevent the liquid from boiling. The solution was then filtered, and on standing for some hours the colouring principle was deposited in small prisms arranged in stars. By repeated digestions with alcohol and animal charcoal it was rendered colourless, when it had a silky lustre. A considerable portion of the original precipitate however did not dissolve in the alcohol, and consisted of a brownish coloured humus-like substance.

The colouring principle of the *Gyrophora pustulata*, which I shall call gyrophoric acid, when pure forms small white soft crystals, which have neither taste nor smell. It is almost insoluble both in cold and in boiling water. It is also but sparingly soluble both in ether and in alcohol. It is much less soluble therefore in hot alcohol than either orsellic, lecanoric or erythric acids. Its solutions have no action upon test-paper. Gyrophoric acid has no saturating power, for the smallest quantity of either potash or ammonia gives its solutions an alkaline reaction. When gyrophoric acid is boiled for a short time with a considerable excess of any of the alkalies or alkaline earths, it gives off carbonic acid and is converted into orcine. When, on the other hand, it is boiled with a very small portion of alkali only, it is decomposed in the same way as the orsellic, erythric and other similar acids, and yields a corresponding intermediate acid, which is more soluble in water and exhibits more distinctly acid properties than the gyrophoric acid from which it has been derived. Gyrophoric acid strikes the same bright red fugitive colour with hypochlorite of lime which appears to be characteristic of this class of colouring matters. The red solution which it yields is however rather more durable than those of the above-mentioned acids. Gyrophoric acid is very slightly soluble even in a large excess of a cold aqueous solution of ammonia, and it is precipitated by ammonia from its alcoholic solution, without however combining with any of that alkali. When gyrophoric acid is heated with an alcoholic solution of ammonia it readily dissolves, but at the same time it is decomposed with the formation of an intermediate acid. When gyrophoric acid is macerated with an excess of ammonia and exposed for a considerable time to the air, it is slowly converted into a purplish-red colouring matter similar to that which the analogous acids furnish in the same circumstances.

A quantity of gyrophoric acid, prepared in the way already described and repeatedly washed with boiling water to free it from any trace of the ether compound which might have adhered to it, was subjected to an analysis:—

I. 0·2785 grm. substance dried *in vacuo*, and burned with chromate of lead, gave 0·621 carbonic acid and 0·123 water.

II. 0·175 ditto gave 0·3925 Co^2 and 0·082 water.

III. 0·1798 substance gave 0·403 carbonic acid and 0·081 water.

Calculated numbers.		per cent.	I.	Found. II.	III.
36 C	2700	61·02	60·81	61·16	61·12
18 H	225	5·09	4·90	5·20	5·00
15 O	1500	33·89	34·29	33·64	33·88
	4425	100·00	100·00	100·00	100·00

These numbers therefore give $C_{36}\ H_{18}\ O_{15}$ as the formula of gyrophoric acid.

Ether compound.

When gyrophoric acid is boiled for some hours in strong spirits of wine it is readily converted into an ether, a considerable quantity of a resinous matter and orcine being also formed during the operation. The ether is very soluble in hot water, and is purified from adhering resinous matter exactly in the same way as the ethers of the orsellic, lecanoric and analogous acids, which in its external properties it very closely resembles.

I. 0·2532 grm. ether dried *in vacuo*, gave with chromate of lead 0·570 Co^2 and 0·144 Ho.

II. 0·278 substance gave 0·625 carbonic acid and 0·155 water.

Calculated numbers.			Found numbers. I.	II.
C 40	3000	61·39	61·33	61·31
H 23	287	5·87	6·31	6·19
O 16	1600	32·74	32·36	32·50
	4887	100·00	100·00	100·00

These numbers give $C_{36}\ H_{18}\ O_{15} + C_4\ H_5\ O_1$ as the rational formula of the gyrophoric ether.

Gyrophoric acid also readily forms a corresponding methyl compound when it is boiled for some hours with wood-spirit. In all its characters it perfectly agrees with the analogous compounds of lecanoric and orsellic acids.

Gyrophoric acid dissolves very readily in a slight excess of baryta, and when the solution is supersaturated by an acid the gyrophoric acid precipitates unchanged. A quantity of gyrophoric acid was dissolved in a cold solution of baryta and the excess of the base removed by a stream of carbonic acid. The precipitate, which consisted of a mixture of carbonate of baryta and the organic salt, was collected on a filter and dried by a gentle heat. The dried precipitate was then repeatedly digested in strong spirits of wine, in which the organic salt dissolved, though with difficulty, the carbonate of baryta remaining on the filter. On standing for some time, the clear solution deposited the baryta compound in silky crystals. This salt is insoluble in cold alcohol. The hot spirits appear to have partially altered it, for on subjecting it to analysis, though it appeared to have an uniform composition, yet on decomposing it

by an acid and recrystallizing, the organic acid it contained was found to have a different composition from that of gyrophoric acid; from which it also differed in its properties, being much more soluble in water and also more distinctly acid.

An alcoholic solution of gyrophoric acid gives no precipitate with an alcoholic solution of sugar of lead, but it yields a pretty bulky precipitate with both an aqueous and an alcoholic solution of subacetate of lead. Though I made many trials I was unable to obtain these precipitates of anything approaching to an uniform composition. Neither was I more successful in forming any other definite compounds of gyrophoric acid by which its atomic weight might have been more definitely ascertained.

Lecanora tartarea.

This lichen, like the *Gyrophora pustulata*, has been employed from a very early period in the manufacture of archil. The *Lecanora tartarea* is found in considerable abundance in the hilly districts of the northern parts of both Scotland and Ireland, though what is usually met with in commerce is chiefly obtained from Norway and its neighbouring countries. The lichen on which I operated was from Norway. Its colouring principle was extracted by milk of lime, exactly in the way already described. The quantity of colouring principle it contained was, comparatively speaking, small, not exceeding that in the *Gyrophora pustulata*. The precipitate thrown down from the lime solution by muriatic acid had a brownish-red colour. It was washed with cold water, collected on a cloth filter and cautiously dried. It was then digested with a little dilute spirits, which removed a greenish coloured resinous substance precisely similar to that contained in the *Gyrophora pustulata*. The portion of the precipitate which did not dissolve in the weak spirits was next digested in strong alcohol assisted by a considerable quantity of animal charcoal. The filtered solution deposited the colouring principle in small silky prisms arranged in stars. These crystals at first had a yellowish tinge, but by being repeatedly digested with animal charcoal, they were rendered quite colourless. A considerable portion of the original gelatinous precipitate did not dissolve in the hot alcohol, and appeared, as in the case of the preceding lichen, to consist of a brownish coloured humus-like substance. The purified acid from the *Lecanora tartarea* was dried *in vacuo* and burned with chromate of lead.

I. 0·153 substance gave 0·342 Co^2 and 0·071 water.

II. 0·250 substance gave 0·561 Co^2 and 0·115 water.

Calculated numbers.		per cent.	Found numbers. I.	II.
36 C	2700	60·02	61·96	61·20
18 H	225	5·09	5·15	5·10
15 O	1500	33·89	33·89	33·70
	4425	100·00	100·00	100·00

These numbers give $C_{36}H_{18}O_{15}$ as the formula of the acid in the *Lecanora tartarea*, which is exactly the formula of gyrophoric acid. In fact the acid in the *Lecanora tartarea* is identical in all its properties and reactions with the acid in *Gyrophora pustulata*, so that no doubt can be entertained that both lichens contain one and the same colouring principle, viz. gyrophoric acid.

The Ether Compound.

Gyrophoric ether was also formed by boiling the acid from the *Lecanora tartarea* in strong spirits. As might have been expected, it proved also identical in composition and properties with that obtained from the acid of the *Gyrophora pustulata*. The following are the results of its analysis:—

I. 0·337 grm. ether dried *in vacuo* and burned with chromate of lead, gave 0·7595 carbonic acid and 0·191 water.

II. 0·296 grm. gave 0·6658 carbonic acid and 0·165 water.

	Calculated numbers.		Found numbers.	
		per cent.	I.	II.
C 40	3000	61·39	61·46	61·30
H 23	287	5·87	6·29	6·19
O 16	1600	32·74	32·25	32·51
	4887	100·00	100·00	100·00

The rational formula for the gyrophoric ether from the acid in the *Lecanora tartarea* is therefore $C_{36}H_{18}O_{15}+C_4H_5O_1$.

It is certainly not a little singular that the ether compounds of this whole series of acids, the lecanoric, the erythric, the alpha and beta orsellic acids, and here again the gyrophoric acid, should approach each other so closely in their general properties and in their per cent. composition. Mr. Schunck has been induced by this circumstance to think it probable that all this class of acids are coupled acids containing lecanoric acid and an adjunct, and that the ethers which they yield are in fact only one compound, viz. lecanoric ether. Mr. Schunck's hypothesis is, however, much weakened from the fact that we possess no means of reproducing lecanoric acid from the so-called lecanoric ether, for when any of these ethers are acted on by an alkali, the organic acid they contain undergoes decomposition as well as the compound itself. Besides, it appears somewhat gratuitous to infer merely from the per cent. composition of these ethers that they all contain lecanoric acid, and are in fact lecanoric ether, as any person may easily convince himself, by a few trials, that considerable alterations may be made on the formulæ of these acids without materially affecting the per cent. composition of their ethers.

Brom-orcine.

In the former paper on the proximate Principles of some of the Lichens, read before this Society on the 3rd of February 1848, I described a crystalline body ob-

tained by cautiously pouring bromine into a concentrated aqueous solution of orcine, giving at the same time an analysis of the compound and a description of its properties. An abstract of the paper containing most of these particulars was published in the Athenæum and Chemical Gazette for March, and in the London Philosophical Magazine for April 1848. Notwithstanding all this, in the Comptes Rendus for August 1848, Messrs. Laurent and Gerhardt describe this very compound with exactly the same properties, and obtained in precisely the same way, without so much as ever hinting that it had been previously discovered. Messrs. Laurent and Gerhardt, however, give a different formula for the compound, which I am also disposed to adopt, as on repeating my analysis of it I find I had somewhat over-estimated the amount of bromine contained in it, while its other constituents were determined correctly enough. The following are the results of the corrected analysis of brom-orcine:—

I. 0·361 grm. substance dried *in vacuo* gave 0·5628 Ag Br=0·2395 Br=66·34 per cent. Br.

II. 0·3615 gave 0·565 Ag Br=0·2404 Br=66·50 per cent. Br.

III. 0·281 gave 0·438 Ag Br=0·1864 Br=66·33 per cent. Br.

0·264 substance dried *in vacuo*, and burned with chromate of lead, gave 0·227 carbonic acid and 0·0367 water.

Brom-orcine.			Found numbers.		
Calculated numbers.		per cent.	I.	II.	III.
14 C	1050·00	23·27	23·44		
5 H	62·50	1·39	1·54		
3 Br	2998·89	66·47	66·34	66·50	66·33
40	400·00	8·87	8·68		
	4511·39	100·00	100·00		

The rational formula of brom-orcine is therefore $C_{14} H_5 Br_3 O_4$, or orcine in which three equivalents of hydrogen are replaced by bromine.

The following is the composition of anhydrous orcine:—

0·349 grm. orcine dried *in vacuo* over So_3 for some weeks, and burned with chromate of lead, gave 0·8675 carbonic acid and 0·205 water.

Calculated numbers.		per cent.	Found numbers.
C 14	1050·0	67·75	67·80
H 8	99·8	6·44	6·52
O 4	400·0	25·82	25·68
	1549·8	100·00	100·00

Beta-orcine.

The London Philosophical Magazine for July 1848 contains a description of a compound to which I have given the name of beta-orcine, from the great analogy

which it bears to orcine both in the mode of its formation and in most of its properties. Beta-orcine may be obtained by two processes; either by destructively distilling usnic acid, or by acting on that body by alkalies. It crystallizes very beautifully in four-sided prisms surmounted at either end by well-defined four-sided pyramids. It is very soluble in water, alcohol and ether. Its solutions are perfectly neutral. Its crystals are hard and brittle, have a brilliant lustre, and are usually from an inch to three quarters of an inch long.

Beta-orcine has a faintly sweetish taste. In the course of a few minutes it assumes with ammonia a beautiful blood-red colour, which on standing becomes deeper. Beta-orcine is therefore much more rapidly acted on by ammonia than ordinary orcine. The smallest portion of beta-orcine instantly strikes a bright blood-red colour with a solution of hypochlorite of lime; just as alpha and beta orsellic acids, erythric, lecanoric and gyrophoric acids do with the same reagent. Ordinary orcine, on the other hand, yields a violet purple colour with hypochlorite of lime. The formula which I now propose for beta-orcine is $C_{16}H_{10}O_4$, that of orcine being $C_{14}H_8O_4$. I have inserted this short notice of beta-orcine merely to complete the series of this class of bodies.

Quintonitrated-erythromannite.

In the former paper on the lichens, already so often referred to, I have described under the name of pseudo-orcine, a remarkably beautiful crystalline body, which is obtained by boiling either picro-erythrin or erythric acid itself, with an excess of lime or baryta. I have subsequently been induced to change the name of this compound to that of erythromannite, as indicating at once its origin and its most characteristic properties. It was mentioned in the previous paper that I then regarded erythromannite as very analogous to mannite in its properties, and from an experiment I have recently made this conjecture has received very ample confirmation. About two years ago, Messrs. Flores Domonte and Menard obtained a curious detonating compound by dissolving mannite in fuming nitric acid kept carefully cooled, and then adding an equal bulk of sulphuric acid to the solution. The compound, which is crystalline, is deposited on the cooling of the liquid. It is first washed with cold water, in which it is insoluble, to free it from adhering acid, and then dissolved in boiling spirits of wine, out of which it crystallizes in long silky needles. Mannite-quintinitrique, as these French chemists have called it, possesses the remarkable property of detonating so violently when struck with a hammer, that M. Sobrero has proposed employing it for the manufacture of percussion caps instead of fulminate of mercury.

As might naturally have been expected, from the great similarity in composition and properties which mannite and erythromannite have to each other, erythromannite, when treated with fuming nitric acid, also yields a nitrated compound perfectly analogous to quintonitrated-mannite. In order to prepare this compound certain pre-

cautions are requisite, which I shall shortly describe. Erythromannite in the state of powder is to be slowly added to a quantity of fuming nitric acid kept at a low temperature. The erythromannite rapidly dissolves, while considerable heat is evolved. So soon as a complete solution is effected, rather more than an equal bulk of sulphuric acid must be cautiously added to the solution. When the mixture has stood for half an hour, it becomes filled with a magma of crystals. These are collected in a funnel stopped with asbestos, and are left to drain. They are next washed with cold water, in which they are insoluble, till all adhering acid is removed, and then dried by pressure between sheets of blotting-paper. The compound is then boiled with moderately strong spirits, in which it readily dissolves, and on the cooling of the liquid it is deposited in large flat crystals resembling those of benzoic acid, only larger, and exhibiting a great deal of a mother-of-pearl lustre.

It might naturally be supposed that this compound would also be formed by dissolving erythromannite in a mixture of equal parts of fuming nitric and sulphuric acids, and that it would be thrown down by adding a sufficient quantity of water. This is not the case, however, either with it or with the mannite compound, which can only be procured in the way already described, by employing the nitric acid first, and precipitating the nitrated compounds by adding the sulphuric acid afterwards. The solutions of nitrated erythromannite are quite neutral to test-paper. When nitrated erythromannite is heated to 61° C. it melts, but recrystallizes immediately when cooled a few degrees below that temperature; when strongly heated, it takes fire and burns with a gentle deflagration. When, however, the dried crystals are mixed with a little sand and are struck with a hammer, they detonate with great violence. This reaction clearly shows the close analogy that subsists between nitrated erythromannite and quintonitrated mannite, which will appear still more distinctly on comparing the results of their analysis. As however this relation equally subsists between mannite and erythromannite, I shall first subjoin the formulæ and analyses of these two bodies also, so that the intimate relation existing among these four compounds may be rendered more distinctly perceptible.

0·4702 grm. erythromannite, dried *in vacuo* and ignited with chromate of lead, gave 0·679 carbonic acid and 0·355 water.

Erythromannite.		per cent.	Found.	Mannite.		per cent.
11 C	825	39·29	39·36	C 12	900·0	39·57
14 H	175	8·33	8·60	H 14	174·7	7·67
11 O	1100	52·38	52·04	O 12	1200·0	52·76
	2100	100·00	100·00		2274·7	100·00

The rational formula of mannite is . . . . . $C_{12} H_{14} O_{12}$.

The rational formula of erythromannite is . . $C_{11} H_{14} O_{11}$.

Mannite therefore only differs from erythromannite by containing one equivalent more of carbonic oxide.

I. 0·3755 grm. quintonitrated-erythromannite, dried *in vacuo* and burned with chromate of lead, gave 0·228 carbonic acid and 0·083 water.

II. 0·394 grm. quintonitrated-erythromannite, dried *in vacuo* and burned with chromate of lead, gave 0·241 carbonic acid and 0·089 water.

10 tubes gave 329 measures of mixed gases consisting of 227 carbonic acid and 102 measures nitrogen, or carbonic acid gas in the proportion of eleven to five nitrogen.

Quintonitrated-erythromannite.			Found.		Quintonitrated-mannite.	
Calculated numbers.		per cent.	I.	II.	Calculated numbers.	per cent.
11 C	825	16·75	16·56	16·68	12 C 900·0	17·66
9 H	112	2·27	2·46	2·50	9 H 112·3	2·21
5 N	885	17·98	17·83	17·83	5 N 885·0	17·36
31 O	3100	63·00	63·15	62·99	32 O 3200·0	62·77
	4922	100·00	100·00	100·00	5097·3	100·00

The rational formula of quintonitrated-erythromannite is therefore $C_{11}H_9O_6 + 5NO_5$ = erythromannite, in which five equivalents of water are replaced by five equivalents of nitric acid, and corresponding exactly in this respect with quintonitrated-mannite, in which five equivalents of water are also replaced by five equivalents of nitric acid. I conclude by subjoining the formulæ of these four compounds, which only differ from each other by one equivalent of carbonic oxide, that so their mutual relations may be seen at a glance.

Mannite . . . . $C_{12}H_{14}O_{12}$. Quintonitrated-mannite . . . . $C_{12}H_9O_7 + 5NO_5$.
Erythromannite $C_{11}H_{14}O_{11}$. Quintonitrated-erythromannite $C_{11}H_9O_6 + 5NO_5$.

Glasgow, 12*th February* 1849.

XXI. *On the Structure of the Dental Tissues of Marsupial Animals, and more especially of the Enamel.* By JOHN TOMES, *Surgeon-Dentist to the Middlesex Hospital. Communicated by* R. E. GRANT, *M.D., F.R.S., Professor of Comparative Anatomy and Zoology at University College.*

Received June 21,—Read June 21, 1849.

MY DEAR DR. GRANT,

ON making microscopic examinations of the teeth of one or more species of the several families of the marsupial animals, the skulls of which you kindly placed at my disposal, I found some peculiarities of structure, which so far as I know have not hitherto been recognised, and which will I think be found to constitute a pretty constant character in the teeth of this order of quadrupeds. It is my present purpose to describe these peculiarities, and should the communication seem sufficiently interesting and important to engage the attention of the Royal Society, my debt of gratitude, already great, will be rendered yet greater by your lending your name for its presentation.

Professor OWEN, in his Odontography (p. 397), when treating on the structure of the marsupial teeth, says, "The dentine, enamel, and cement of the teeth of marsupial animals, present the usual microscopic characters of these tissues in Mammalia." My researches have led me to a different conclusion. The enamel presents a very strongly-marked peculiarity, common (so far as I have examined), with one exception only, to all marsupial teeth, and present only in a very limited number of other mammalian teeth. I have hitherto found it only in the British Shrews, the Hyrax, and in the molar teeth of the Jerboa.

The main peculiarity to which I allude, is that the greater number, if not all, of the dentinal tubes are continued into, and constitute a considerable portion of the enamel. I have in another place* pointed out that in the human teeth the dentinal tubes are in small numbers, and occasionally only continued for a short distance into the enamel; and the same may be said of many other teeth. In these instances however the condition is rudimentary only, but in the marsupial teeth the development of the tubes in the enamel is as perfect as in the dentine itself. It is not difficult to suppose that a portion of the columns of cells, which constitute the enamel pulp, may become developed into tubes continuous with those formed by the columns of cells in the adherent dentinal pulp, instead of being converted into solid enamel fibres which

* Lectures on Dental Physiology and Surgery, p. 35.

occurs in the majority of teeth; and this no doubt does happen in the marsupial teeth, and also in some few others. Indeed in all teeth the enamel fibre is in an early stage of formation partially tubular*.

I will now proceed to describe the teeth in those species of marsupials that I have examined; for I find many minor points of dissimilarity, by which, on careful comparison, the teeth of allied species may be distinguished the one from the other.

I may remark, however, before doing so, that the enamel presents other points of peculiarity, though less apparent, than its tubularity. In many marsupial teeth the enamel is studded with small cells, often, but by no means always, arranged in contour lines. Then again the fibres are in many teeth so intimately united to each other that their individuality is lost, and this occurs in most teeth in some parts, so that the dimensions of the fibres at such points cannot be taken.

Macropus giganteus.—In this animal the differences in the dental tissues composing the incisor and molar teeth, are chiefly confined to the number of curves described by the enamel fibres and tubes. I shall therefore for the present restrict my description to a transverse section of a lower incisor through the part most thickly coated with enamel.

The dentinal tubes radiate from the pulp-cavity with numerous gentle secondary curves, and when pursuing the latter third of their course before entering the enamel, give off numerous short fine branches. When near the enamel the small branches suddenly cease to be given off, and the parent tubes, either with or without bifurcating, enter the enamel. The absence of the minute lateral tubules renders the tooth more transparent at these than in the neighbouring parts. On entering the enamel the tubes dilate into more or less oval or conical cells, from whence they are continued, and follow in delicate undulations the course of the enamel fibres, some few giving off on their way one or two branches. They gradually diminish in size till they are eventually lost near the surface of the enamel, either from their own minuteness or from their entering small opaque cells, which are common near the outer surface of this texture, Plate XXXV. fig. 1 A, the dentine; B, the enamel. The enamel fibres in the thickest part of the tooth are subject in their course outwards to four, five, and sometimes to even six flexures, fig. 2 B. As they arise from the periphery of the dentine, they proceed upwards in a tolerably straight line towards the cutting margin of the tooth; they then turn downwards at an angle of ninety degrees with their first course, and after advancing about as far in the second as they did in the first line, they describe several lesser flexures having similar angles to the first. When within two-fifths of their termination on the surface, the enamel fibres take a straight and parallel course at right angles with the surface of the tooth.

As the coating of enamel becomes thinner, both towards the cutting edge and at the lower part of the tooth, the lesser curvatures of the fibres are lost, and the direction of the first large flexure is reversed; so that the fibres proceed first downwards

* Lectures on Dental Physiology and Surgery, p. 102.

and then upwards. Near the surface numerous small opaque cells are found irregularly interspersed amongst the enamel fibres, or arranged in contour lines.

In the molar teeth the enamel fibres which arise from the depressions on the masticating surface describe several curves, while those from the sides of the tooth and of the tubercles have but one flexion, and even this is lost where the enamel thins previous to its termination on the neck of the tooth.

The tubes here, as in the incisors, accompany the fibres, but those which arrive near the apex of the tubercles wind round in a spiral course, fig. 3. When the enamel becomes thin previous to its cessation, the tubes are less abundant; and at its termination few, if any, are seen in this or any of the marsupial teeth. When speaking of the enamel in the incisors of the Kangaroo, Professor Owen says*, "The fibres of the enamel which invest the crown of the large lower incisor are likewise unusually minute; viewed in a transverse section, as in plate 102 *e e*, they describe an abrupt curve at their commencement, and then proceed in a nearly straight course to the surface; but at the trenchant margins of the tooth their course is curved, and they decussate one another, as represented in the figure†. Some of the enamel *lines* at this part seem to be as fine as the dentinal tubes." Professor Owen has evidently seen the enamel tubes in this tooth, but from some cause has failed to recognise them as such. In the same page he says, "The terminal branches of the (dentinal) tubuli open into minute irregular cells, forming a thin boundary layer between the dentine and enamel." These cells are certainly not between the dentine and enamel in any of the sections I have made, but are distinctly enough visible in the enamel, and form part of the continuous dentinal and enamel tubes.

In conducting the examination of this tooth and of the teeth I am about to describe, I have made at least half-a-dozen sections, taken from different parts and in different directions of the tooth for the purpose of avoiding error.

Professor Owen states, that the dentinal tubes are the $\frac{1}{18,000}$th of an inch in diameter. In the specimens I have examined, they have averaged $\frac{1}{10,000}$th of an inch at their commencement at the pulp-cavity, have gradually diminished, and on entering the enamel have not exceeded the $\frac{1}{20,000}$th of an inch. On dilating they reach $\frac{1}{8000}$th, and again contract to the $\frac{1}{20,000}$th of an inch, from which they are reduced gradually to the $\frac{1}{30,000}$th and are lost.

The enamel fibres measure $\frac{1}{8000}$th and are cylindrical or oval in their transverse section. The dentinal tubes in the root of the teeth vary in diameter in different parts of their course, and are oval in a transverse section. At their commencement they are the $\frac{1}{8751}$st, but at the middle of their course they reach the $\frac{1}{3000}$th of an inch in diameter, in addition to which they are subject to short local dilatations. In this part of the tooth branches are given off almost from the commencement of the

* Odontography, p. 397.

† Plate 102, fig. 1. "One-half of a transverse section of the lower incisor of a Kangaroo (*Macropus major*), showing the course of the dentinal tubes at *d* and the fine fibres of the thick enamel at *e*."

tubes; these recurve and present their convexities towards the outer surface of the tooth.

Near the surface the dentinal tubes break up into an infinite number of delicate branches, resembling tufts of fine moss, effecting at the same part innumerable anastomoses. At and near the extremity of the fang, short branching dentinal tubes are interspersed with cemental cells, but higher up, towards the crown of the tooth, the cement and dentine are separated by a well-defined line of demarcation, across which a few only of the tubes advance to join the branches of the neighbouring cemental cells.

Near the neck of the tooth the cemental cells are often altogether wanting in branches, and approach a circular form.

Hypsiprymnus minor and *penicillatus*.—The teeth of these animals resemble very closely in structure those of the Kangaroos. In the incisors, the enamel being less thick, present but one curve, and that in the direction of the axis of the tooth.

In *Hyp. penicillatus*, the dentinal tubes, on entering the enamel, dilate into irregularly oval or circular cells, measuring about $\frac{1}{10,000}$th of an inch in diameter; they then suddenly contract to $\frac{1}{30,000}$th, and follow the course of the enamel fibres to near the surface; then some few bend to a right angle with their original course and terminate in a point, their terminal course being directed towards the root of the tooth, fig. 4. The fibres of the enamel measure $\frac{1}{7500}$th of an inch in diameter.

The dentinal tubes at their commencement at the pulp-cavity measure the $\frac{1}{19,000}$th, and at the point where they enter the enamel the $\frac{1}{30,000}$th of an inch.

In *Hypsiprymnus minor*, the dentinal tubes, on entering the enamel, often do not dilate at all, and when they do, the dilatation is continued for some little distance with an irregular outline. Hence, on accurate comparison, the teeth of the one species of Hypsiprymnus may be distinguished from those of the other.

Phascolomys Wombat.—The teeth of this interesting marsupial are remarkable for the complete absence of tubes in the enamel. The dentinal tubes cease at the line of junction of the dentine with the enamel, and in no case pass across into the enamel. The fibres of the latter texture are clear and transparent; and arising from the peripheral surface of the dentine, after presenting one or two slight undulations, arrive at the surface of the enamel, which in the incisor teeth is invested with a thin layer of cement. The enamel fibres measure about the $\frac{1}{7500}$th of an inch in diameter. Their course is not, as regards each other, everywhere parallel; on the contrary, at certain points intervals will be left by their divergence, which are filled up by supplementary fibres; then again bundles of fibres converge and cross each other. I have failed to observe the transverse striæ mentioned by Prof. Owen*. The fibres have sometimes a slightly irregular outline, which gives an appearance of unequal dimensions to different parts of the same fibre, and not unfrequently longitudinal central lines may be seen, like the persistent nuclei of the developmental cells.

* Odontography, page 398.

The dentinal tubes are, at the pulp-cavity, about the $\frac{1}{10,000}$th of an inch in diameter, and at the peripheral ends $\frac{1}{80,000}$th of an inch. The tubes, as they leave the pulp-cavity, advance upwards towards the surface of the tooth, but in the latter part of their course they bend outwards, and thus describe large curves, the convexities of which are directed towards the masticating surface. Until within the $\frac{1}{875}$th of an inch of the enamel the dentinal tubes give off very few branches, but when they have arrived at that point, and for a short distance onward, they give off numerous tubules which form a dense meshwork of tubes in a contour line with the enamel, fig. 5.

Professor Owen, in the work already referred to—the standard work on Odontography in our language,—mentions that medullary canals are prolonged into the substance of the dentine, and also that many of the dentinal tubes terminate in cells on the periphery of the dentine. Of this I have now to speak.

Out of this meshwork of branching and anastomosing tubes a few are continued into a comparatively clear space about the $\frac{1}{750}$th of an inch broad, and terminate either in irregular cells which vary from the $\frac{1}{6000}$th to the $\frac{1}{15,000}$th of an inch in diameter, or by anastomosis. None however cross into the enamel. That portion of the tooth which lies towards the mouth is not invested with enamel, but is covered by a thin layer of cement, between which and the dentine there is no distinct line of demarcation. Into the cells of this run the terminal branches of the dentinal tubes. The cement is continued over the surface of the enamel in a layer of about the $\frac{1}{750}$th of an inch in thickness, and this is tenanted by a single line of cells.

These teeth closely resemble, as well in structure as in external form, those of the Rodents, and especially the Hare and Rabbit.

Phalangista vulpina.—The dentinal tubes of the molar teeth of this creature arise at the pulp-cavity, with a diameter of about the $\frac{1}{10,000}$th of an inch, and pursue a slightly undulating course until they have accomplished two-thirds of their whole distance; they then bend downwards from the crown, and give off innumerable minute tubules. When within a short distance of the enamel they dichotomize once or twice, and enter that structure with a diameter of about the $\frac{1}{80,000}$th of an inch, fig. 6.

On passing into the enamel the tubes occasionally dilate into an oval or oblong cell of from the $\frac{1}{7500}$th to the $\frac{1}{10,000}$th of an inch in diameter, but far more commonly they undergo no dilatation. Others again dilate into an oval or long cell. When they have passed half or two-thirds through the enamel, some few divide once or twice into two branches. After following an undulating course until near the surface of the tooth, they terminate in small cells or become imperceptibly minute. The tubes in the enamel have a diameter varying from the $\frac{1}{15,000}$th to the $\frac{1}{20,000}$th of an inch.

The dentinal tubes, near their commencement at the pulp-cavity, in about the middle part of the fang, commonly reach a diameter of the $\frac{1}{6000}$th of an inch. They give off branches during the whole of their course, and terminate in a dense anasto-

mosing plexus of tubes, from which many pass to the cells of the cement; hence these two tissues are not separated from each other by a strongly-marked line of demarcation, such as obtains in some other teeth of marsupial animals.

Petaurus taguanoides.—The molar teeth of this interesting animal, though possessing the marsupial characteristic strongly marked, yet are so different under the microscope from those I have already described as to be recognised at first sight. The dentinal tubes at their commencement at the pulp-cavity have a diameter not exceeding the $\frac{1}{15,000}$th of an inch. They follow a slightly undulating course to about two-thirds of their length; they then make one large curve, the concavity of which is usually directed towards the crown of the tooth. At no part of their course do the dentinal tubes of the crown give off branches until they arrive at the enamel; then a few, and a few only, divide into two branches, and are continued into that tissue. The tubes, on entering the enamel, make a small curve downwards, corresponding in direction to that in the dentine just described; they then follow an upward course, and are lost near the surface. The tubes usually suffer no change of dimensions on passing into the enamel, but generally keep a diameter of about $\frac{1}{60,000}$th of an inch, till they are lost in small opaque markings that are common in the enamel near its surface, Plate XXXVI. fig. 7.

The dentinal tubes of the fangs of these teeth are perceptibly larger than those of the crown, and very commonly have a ragged outline, or are composed of lines of cells. They give off but comparatively few branches, and these only near the surface of the fang.

In the incisor teeth the dentinal tubes branch more abundantly than in the molars, and are less frequently continued into the enamel.

In the fangs of the lower incisors the tubes are distinctly oval in section, having a greater diameter of $\frac{1}{7500}$ and lesser of $\frac{1}{15,000}$. The final large curve also has its convexity directed towards the crown of the tooth.

Petaurus sciureus.—The structural characters of the teeth of this animal closely resemble those of *P. taguanoides*. There are however differences by which, on comparison, the one may be known from the other. The dentinal tubes in their course from the pulp-cavity towards the crown arch with the convexity directed upwards; then again they give off numerous fine branches during the latter third of their course. In the fangs they dichotomize during the latter half of their length, but do not form the rich plexuses of tubes common in the Kangaroos; neither do the branches go off at a right angle; on the contrary, they follow much the same course as the parent tube. The fang is plentifully supplied with cement, which contains a few cells of very elongated form, with the long axis in the direction of that of the tooth. In addition to these there are great numbers of tubes placed parallel with each other, and at right angles with the surface of the tooth.

Dasyurus ursinus.—The dentinal tubes of the crown of the tooth advance at a right angle with the surface of the pulp-cavity. Those which form the upper part of the

crown proceed upwards, then in a large curve bend outwards, and when within the $\frac{1}{1000}$th of an inch of the enamel give off an abundance of short fine tubules, and when so doing turn upwards, having but few previously, and none at all until within half-way of the enamel. On entering the enamel they again make a small curve downwards, give off occasional branches, and make numerous short deflections downwards, and after advancing through about two-thirds of the thickness of the enamel are lost, fig. 8.

The tubes at the pulp-cavity measure about $\frac{1}{10.000}$th of an inch in diameter, and on entering the enamel $\frac{1}{30.000}$th of an inch; when within the enamel they increase to about the $\frac{1}{30.000}$th, and gradually diminish till they become invisible, or are lost in small cells. On the lingual surface of the tooth, the tubes in this, as in many other marsupial teeth, commence by small cells.

The dentinal tubes of the fangs are lost in the cement, between which and the dentine there is no strongly-marked line of demarcation. The cemental cells are large, elongated in figure, and have many and large tubules.

In the molar teeth of *Dasyurus macrourus* the dentinal tubes branch more sparingly, and on entering the enamel are not subject to the same degree of deflection, though possessed of the same general character as those seen in the *D. ursinus*; neither do they suffer any enlargement in the first part of their course, as is common in the last-mentioned tooth, fig. 9.

The cemental cells are more simple in form, and the dentine and cement are separated by a well-marked line of junction, except at the apex of the fang, where the cement is reflected for a short distance up the canal.

In the canine teeth of this animal a considerable portion of the lower end of the fang is made up of cement. In the concave lingual surface of the crown the enamel is thin, and the tubes frequently commence in small cells. The dentinal tubes give off small branches during the greater part of their course, and when close to the enamel occasionally turn upward and dilate into elongated cells.

Thylacinus cynocephalus.—The teeth of this creature have a strong family resemblance to those of the *Dasyuri* last described. There are however minute points of difference. The dentinal tubes, in addition to giving off minute short pilose branches, on nearing the enamel divide into several large branches, fig. 10 A. They are likewise more disposed to dilate on entering the enamel, though many proceed without marked increase of size. Then, again, the tubes are lost by the time they have gained the inner fifth of the whole thickness of the enamel; and the enamel fibres are more distinctly marked than in either of the preceding species excepting the Wombat, thereby approaching in structure to the teeth of the ordinary carnivora, fig. 10. The dentinal tubes, on leaving the pulp-cavity to proceed towards the coronal surface, have a diameter of about the $\frac{1}{10.000}$th of an inch; on reaching the periphery the $\frac{1}{43.857}$th, and in the first part of their course in the enamel the $\frac{1}{30.000}$th. Those destined for the upper part of the crown advance upwards, and then make one large

bold curve outward, with the convexity directed upwards; in the fang they make a second large curve with the concavity directed upwards.

The tubes, when in the enamel, in addition to a multitude of minute undulations, describe one large curve with the concavity directed upwards. They for the most part rapidly diminish in size; sometimes, however, they dilate into small cells, and again continue their course. Previous to terminating some few give a number of small branches from their convex side (fig. 10 B), which rapidly diminish in size and are lost. At about the point where the tubes are lost the enamel fibres become tolerably distinct, though with a somewhat ragged indefinite outline. Their diameter is about the $\frac{1}{10,000}$th of an inch; and they take a tolerably direct course outwards. I have stated that the enamel fibres of the tooth of the Thylacinus resemble in a slight degree those of ordinary carnivora, but the one structure cannot for a moment be mistaken for the other, see figs. 10 and 11. Small cells are scattered through the enamel of the Thylacinus and near the surface in contour lines.

The dentinal tubuli of the fang terminate in a granular layer, which, excepting near the extremity of the fang, is separated from the cementum by a strongly-marked boundary line.

The cells of the cementum have no peculiarity; they are arranged in linear series, their long axes being in the direction of that of the tooth. The cement is tolerably abundant in quantity, and at the apex of the fang is pierced by canals for vessels.

Didelphis virginiana.—The teeth of this species were from the skull of an old animal, and though much worn by use yet sufficient remained for my purpose. The marsupial characters, so far as I have had the means of observing, are strongly marked. The dentinal tubes on leaving the pulp-cavity have a diameter of about the $\frac{1}{15,000}$th of an inch. Those that are destined for the masticating surface make one or two large in addition to numerous gentle secondary undulations. But all that depart for the sides of the crown or the tubercles, make a curve on nearing the enamel, the concavity of which is directed upwards, fig. 12 A. During this part of their course they give off from either side, but more especially from the convex side, numerous small, short, delicate branches. Finally, they break up into several branches, which on passing into the enamel preserve their dimensions, the $\frac{1}{42,857}$th of an inch.

When within the enamel the tubes advance to near the surface, which, as the enamel is not thick, is no great distance. In their course, they are subject, in addition to small undulations, to one or two deflections, the concavities of which are directed towards the grinding surface of the tooth, and some few give off one or two branches.

The cementum is abundant, and contains numerous highly developed cells, which give off many branching and anastomosing canaliculi, which form a tolerably uniform meshwork of tubes throughout the whole mass. The extremities of the fangs are constituted of cement, through which anastomosing canals for vessels pass towards the pulp-cavity. The cementum and dentine, though separate at some parts, at

others pass into each other, and are so gradually and intimately blended that it would be impossible to determine to which tissue a given point belonged.

The facts that I have stated lead, I think, to two conclusions. First, that the existence of fully developed tubes in the enamel continuous with those of the subjacent dentine, is common to the teeth of at least the great majority of marsupial animals, if not all, excepting the Wombat. And, secondly, that the enamel and dentine are so closely related, that the one should almost be regarded as a modification of the other, rather than as a tissue of a wholly different nature.

The sections from which the foregoing descriptions have been written, form part of an extensive series in my possession. The accuracy of the statements may therefore at any time be tested.

I remain, my dear Sir, yours faithfully,

June 20th, 1849. JOHN TOMES.

To Robert E. Grant, M.D., F.R.S.

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EXPLANATION OF THE PLATES.

PLATE XXXV.

Fig. 1. A section from crown of a molar tooth of *Macropus giganteus*, showing the tubes of the dentine A in the latter part of their course, and continued into the enamel B, that part only near the dentine being shown. C, a continuous dentinal and enamel tube more highly magnified.

Fig. 2. A transverse section through the lower incisor of the same animal. A, the dentine. B, the enamel in its whole thickness, showing the curves of the fibres.

Fig. 3. The apex of one of the tubercles from the crown of a molar tooth of *Macropus giganteus*, showing the whole thickness of the enamel, B, containing cells in the contour lines, and showing also the spiral course of the enamel tubes near the apex of the tubercles. A, the dentine.

Fig. 4. A longitudinal section from a premolar tooth of *Hypsiprymnus penicillatus*, showing the outer part of the dentine A, and the whole thickness of the enamel B, with the tubes in each. C, the same more highly magnified.

Fig. 5. A longitudinal section from a lower incisor of the Wombat, showing the dentine A, with the manner of termination of the dentinal tubes. B, the enamel, and C, the cement.

Fig. 6. A longitudinal section of a tubercle from a molar of *Phalangista vulpina*, showing A, the dentine, and B, the enamel with their tubes.

PLATE XXXVI.

Fig. 7. A longitudinal section from the crown of a molar tooth of *Petaurus taguanoides*, showing A, a portion of the dentine with its almost branchless dental tubes, and B, the enamel in whole thickness.

Fig. 8. A longitudinal section from the tooth of *Dasyurus ursinus*, showing a portion of the dentine A, and the whole thickness of the enamel B, with the tubes of each.

Fig. 9. A similar section of the tooth of *Dasyurus macrourus*.

Fig. 10. A longitudinal section of the last molar from the lower jaw of *Thylacinus cynocephalus*, showing A, a portion of the dentine, and B, a portion, but not the whole thickness of the enamel.

Fig. 11. A section from the canine tooth of the Leopard, showing A, the peripheral part of the dentine, and B, the enamel. The latter is typical of the enamel of the ordinary carnivora, the fibres of which measure the $\frac{1}{5000}$th of an inch in diameter*.

Fig. 12. A longitudinal section of a molar tooth of *Didelphis virginiana*, showing A, the dentine at its termination, and B, the enamel in its whole thickness, with the tubules in each texture.

* This figure is introduced to show the differences between the enamel in the ordinary carnivora and in the marsupial carnivora.

XXII. *On the Anatomy and the Affinities of the Family of the* Medusæ. *By* Thomas Henry Huxley, *Esq., Assistant-Surgeon of H.M.S. Rattlesnake, now engaged in a Surveying Voyage conducted by* Capt. Stanley *on the Coasts of Australia and New Guinea. Communicated by the* Bishop of Norwich, *F.R.S.*

Received March 29,—Read June 21, 1849.

1. Perhaps no class of animals has been so much investigated with so little satisfactory and comprehensive result as the family of the *Medusæ*, under which name I include here the *Medusæ*, *Monostomatæ* and *Rhizostomidæ*; and this, not for the want of patience or ability on the part of the observers (the names of Ehrenberg, Milne-Edwards, and De Blainville, are sufficient guarantees for the excellence of their observations), but rather because they have contented themselves with stating matters of detail concerning particular genera and species, instead of giving broad and general views of the whole class, considered as organized upon a given type, and inquiring into its relations with other families.

2. It is my intention to endeavour to supply this want in the present paper—with what success the reader must judge. I am fully aware of the difficulty of the task, and of my own incompetency to treat it as might be wished; but, on the other hand, I may perhaps plead that in the course of a cruise of some months along the east coast of Australia and in Bass's Strait I have enjoyed peculiar opportunities for investigations of this kind, and that the study of other families hitherto but imperfectly known, has done much towards suggesting a clue in unravelling many complexities, at first sight not very intelligible.

3. From the time of Peron and Lesueur downwards, much has been said of the difficulties attending the examination of the Medusæ. I confess I think that they have been greatly exaggerated; at least, with a good microscope and a good light (with the ship tolerably steady), I never failed in procuring all the information I required. The great matter is to obtain a good *successive* supply of specimens, as the more delicate oceanic species are usually unfit for examination within a few hours after they are taken.

Section I.—*Of the Anatomy of the Medusæ.*

4. A fully-developed Medusa has the following parts:—1. A disc. 2. Tentacles and vesicular bodies at the margins of this disc. 3. A stomach and canals proceeding from it; and 4. Generative organs, either ovaria or testes. The tentacula

vary in form and position in different species, and may be absent; the other organs are constantly present in the adult animal.

5. Three well-marked modifications of external structure result from variations in the relative position of these organs. There is either—1st, a simple stomach suspended from the centre of a more or less bell-shaped disc, the disc being traversed by canals, on some part of which the generative organs are situated, *e.g. Geryonia, Thaumantias*; or 2ndly, a simple stomach suspended from the centre of a disc; but the generative organs are placed in cavities formed by the pushing in, as it were, of the stomachal wall, *e.g. Aurelia, Phacellophora*; or 3rdly, the under surface of the disc is produced into four or more pillars which divide and subdivide, the ultimate divisions supporting an immense number of small polype-like stomachs; small apertures lead from these into a system of canals which run through the pillars, and finally open into a cavity placed under the disc; the generative organs are attached to the under wall of the cavity, *e.g. Rhizostoma, Cephea.*

6. To avoid circumlocution I will make use of the following terms (employed by Eschscholtz for another purpose) to designate these three classes, viz. Cryptocarpæ for the first, Phanerocarpæ for the second, and Rhizostomidæ for the third.

7. In describing the anatomy of the Medusæ it will be found most convenient to commence with the stomach, and trace the other organs from it.

Of the Stomach.—This organ varies extremely both in shape and in size in the Cryptocarpæ and Phanerocarpæ. But whatever its appearance, it will be always found to be composed of two membranes, an inner and an outer. These differ but little in structure; both are cellular, but the inner is in general softer, less transparent and more richly ciliated, while it usually contains but few thread-cells. The outer, on the other hand, is dense, transparent, and either distinctly cellular or developed into a muscular membrane. It may be ciliated or not, but it is usually thickly beset with thread-cells, either scattered through its substance or concentrated upon more or less raised papillæ developed from its surface.

8. I would wish to lay particular stress upon the composition of this and other organs of the Medusæ out of *two distinct membranes*, as I believe that it is one of the essential peculiarities of their structure, and that a knowledge of the fact is of great importance in investigating their homologies. I will call these two membranes as such, and independently of any modification into particular organs, "foundation membranes."

9. When the stomach is attached to the disc, the outer membrane passes into the general substance of the disc, while the inner becomes continuous with the lining membrane of the canals. There is a larger or smaller space between the inner aperture of the stomach and the openings of the canals, with which both communicate, and which I will therefore call the "common cavity."

10. In the Rhizostomidæ the structure of the stomachs is fundamentally the same, but they are very minute, and are collected upon the edges and extremities of

the ramuscules of a common stem; so that the Rhizostomidæ, *quoad* their digestive system, have the same relation to the Monostome Medusæ as the Sertularian Polypes have to the Hydræ, or the Coralline Polypes to the Actiniæ.

11. If one of the ultimate ramuscules be examined, it will be found to consist of a thick transparent substance, similar in constitution to that of the mass of the disc, through which there runs, nearer one edge than the other, a canal with a distinct membranous wall ciliated internally. From this "common canal" a series of parallel diverticula are given off at regular intervals, and run to the edge of the branch, where they terminate by rounded oblique openings. It is not always easy to see these apertures, but I have repeatedly satisfied myself of their presence by passing a needle or other delicate body into them, figs. 28, 29.

12. The difficulty in seeing the openings arises in great measure from the presence of a membrane which surrounds and overlaps them, and being very irritable, contracts over them on being touched. The membrane consists of two processes, one from each side of the perforated edge of the branch, fig. 28. In *Rhizostoma* these two processes generally remain distinct, so that their bases form a common channel into which all the apertures open; but in *Cephea* they are frequently united in front of and behind each aperture so as to form a distinct polype-like cell, figs. 35, 36.

13. Each membranous process is composed of two membranes; the outer of these is continuous with and passes into the thick transparent outer substance above mentioned (11); the other is less transparent, more richly ciliated, and continuous with the lining membrane of the canals through the apertures. The two membranes are continuous at the free edge of the fold, and are here produced into numerous tentacula. The latter are beset with great numbers of thread-cells, and are in constant motion while the part retains its vitality*, fig. 29.

14. *Of the Disc.*—In the *Medusæ monostomatæ* the outer membrane of the stomach is, as I have said, continuous with the thick transparent mass of the disc, as the inner membrane is with the lining membrane of the canals which traverse it. The disc, therefore, is composed of two membranes inclosing a cavity variously shaped.

15. I have examined the minute structure of the disc in *Rhizostoma*. The outer surface of the transparent mass is covered with a delicate epithelium composed of polygonal nucleated cells joined edge to edge. Among these there are many thread-cells. Beneath this there is a thick gelatinous mass which is made up of an apparently homogeneous substance containing a multitude of delicate fibres interlacing in every direction, in the meshes of which lie scattered nucleiform bodies. On the lower

* M. Milne-Edwards, in his "Observations sur la Structure de la Méduse Marsupiale," describes the fringe and its tentacles, but having altogether overlooked the true digestive apertures, he ascribes to the tentacles the function of villi. "Les franges qui garnissent les bras des rhizostomes sont donc bien certainement des organes d'absorption, et leur structure les rend en effet très propres à remplir cette fonction, qui ici dépend probablement tout entier d'un phénomène analogue à celui désigné par M. Dutrochet sous le nom d'endosmose."

surface of the disc, the only difference appeared to be that the epithelium was replaced by a layer of parallel muscular fibres.

16. It might be said that the gelatinous substance here described is a new structure, and not a mere thickening of the outer membrane; but a precisely similar change is undergone by the outer membrane in the Diphydæ, and here it can be easily traced, *e. g.* in the formation of the bracts and in the development of muscular fibre in the outer wall of the common tube.

17. The structure of the inner membrane of the disc and its canals resembles that of the corresponding tissue in the stomach, &c., but in the ultimate ramifications of the canals it becomes more delicate.

In these points there exists no difference between the Monostome and Rhizostome Medusæ.

18. The three divisions, however, vary somewhat in the arrangement of the cavities and canals of the disc.

In the Cryptocarpæ, the common cavity may be either small (*Thaumantias*) or large (*Oceania*); from it there proceed a number of straight unbranching canals which open into a circular canal running round the margin of the disc.

In the Phanerocarpæ the general arrangement is similar, but the canals frequently branch (*Medusa aurita*, *Phacellophora*) and anastomose in a reticulate manner.

In many of the Monostome Medusæ the centre of the under surface of the disc projects into the "common cavity" as a rounded boss (fig. 11*a*.), and according to its form and size will seem to divide the former more or less into secondary cavities. This appears to me to be the origin of the multiple stomachs of *Medusa aurita* as described by Ehrenberg.

19. In the Rhizostomidæ, the canals of the branched processes unite and open by four (*Rhizostoma*, *Cephea*) or eight (*Cassiopea*?) distinct trunks into a wide curiously-shaped cavity, from whence anastomosing canals are given off to all parts of the disc (figs. 26, 26 *a*.). The circular vessel exists, but is not particularly obvious in consequence of anastomosing branches being given off beyond it.

20. In very many of the Cryptocarpæ (*Carybdoa*, *Oceania* (fig. 5 *a* & *b*.), *Polyxenia*) there is a circular, valvate, muscular membrane developed from the inner and under edge of the disc. In the Phanerocarpæ such a membrane does not seem to be present, but in *Rhizostoma* and *Cephea* it is evidently replaced by the inflexed edge of the disc, fig. 26 *a*.

21. *Of the Marginal Corpuscles.*—In the Cryptocarpæ the marginal corpuscles are sessile upon the circular vessel, figs. 8, 9, 10. They are spheroidal vesicles, containing a clear fluid, and one or more spherical strongly-refracting bodies occasionally included within a delicate cell. The marginal vesicles are placed between the inner and outer membranes of the circular vessel.

In the Phanerocarpæ (*Phacellophora*) the marginal corpuscle (figs. 25, 25 *a*.) is placed at the extremity of a short double-walled tubular pedicle projecting downwards or

towards the ventral surface of the disc; the under margins of the fissure in which it is lodged are prolonged into two overlapping fringes. The cavity of the pedicle is continuous with that of a canal which runs from the common cavity directly towards the corpuscle. Its walls are continuous, the inner with the inner wall of the canal, the outer with the substance of the disc. The pedicle is in fact a mere process of the system of canals, so that the position of the marginal vesicle is relatively to this system the same as in the Cryptocarpæ. A similar remark holds good with regard to the Rhizostomidæ.

22. In *Cephea* and *Rhizostoma* the organ is placed in a notch between two lobe-like processes of the margin of the disc, and looks upwards. On the upper surface a semilunar fold extends from one lobe to the other and covers in the corpuscle; below, the edges of the lobes are thinned and overlap, figs. 33, 34.

23. There are some peculiarities in *Rhizostoma* which deserve to be noticed more fully. On the dorsal surface, behind the semilunar fold above mentioned, there is a large heart-shaped depression (fig. 33) with its base towards the corpuscle. Its surface is thrown into prominent arborescent folds, and is very richly ciliated. The deepest part of the depression is towards its base, and seems to take the direction of the base of the pedicle of the marginal corpuscle, which is just below it. I could not pass a needle from the depression into the cavity of the pedicle, but I have no doubt that they communicate, as on a lateral view the deepest part of the depression seems to project into the cavity of the pedicle. Furthermore, on pressure, the granules usually contained in the cavity of the pedicle sometimes passed into the depression.

24. Ehrenberg describes apertures in *Medusa aurita* by which the system of canals communicates with the exterior, but they are *alternate* with the marginal corpuscles, not under or above them. In *Cephea Wagneri*, again, according to Will, the canals open *beneath* the marginal vesicles. I did not observe this in the *Cephea ocellata*.

25. On the ventral surface a much slighter semilunar fold connects the base of the two lobes, fig. 34. In the centre, behind this, there is an elevation of the substance of the disc, to which the muscular bands which run along the under surface of the disc converge.

26. The canal which runs to the marginal vesicle gives off branches on each side, then opposite the base of the vesicle forms a dilatation rather larger than the cordate depression; from this a cæcal process passes off into each lobe, and so terminates. The termination of the canal in *Cephea* and *Phacellophora* is similar, but in the latter the cæca gives off lateral anastomosing branches, fig. 25.

27. In *Rhizostoma* the pedicle is somewhat bent and enlarged at its upper half. The inner membrane is richly ciliated, and the cavity which it incloses usually contains a number of rounded cell-like bodies floating about in incessant motion. There is a considerable space between the inner and outer membranes, which are thick, and

therefore, when viewed by transmitted light, appear like four thick fibres. The vesicle is about $\frac{1}{170}$th of an inch in diameter, more spherical in small than in large individuals; it contains a closely-packed mass of strongly-refracting granules $\frac{1}{3500}$th of an inch, more or less, in diameter. The outer membrane of the pedicle can be traced over the vesicle, and the inner probably passes under it, separating the cavity of the pedicle from the vesicle: the dense mass of granules prevents this from being actually seen, but from analogy with *Mesonema*, &c., I have no doubt of the fact.

28. Ehrenberg, in his description of the *Medusa aurita*, says, "Le pédoncule est attaché à une vésicule, dans lequel on remarque, sous le microscope, un corps glanduleux, jaunâtre lorsque la lumière le traverse et blanchâtre lorsque cette dernière est réfléchie. De ce corps il part deux branches qui se dirigent vers le pédoncule du corps brun jusqu'à son petit bouton ou tête." And further on, "Le corps bifurqué placé à la base du corps brun paraît être un ganglion nerveux, et ses deux branches peuvent être regardées comme des nerfs optiques." I must confess that, judging by what I have observed in *Rhizostoma* and *Phacellophora*, it appears to me that these so-called nervous branches passing on each side of the pedicle towards its head, are nothing more than the optical expression of the thickness of the two membranes of which the pedicle is composed; and a very similar explanation may, I think, be given of his intertentacular ganglia, which appear to be nothing more than the optical expression of the thickened walls of the circular canal.

29. *Of the Tentacles.*—The tentacles of the Medusæ are of two kinds:—1, those which are processes of the outer foundation membrane alone; and 2, those which are processes of both inner and outer membranes, and therefore contain a cavity continuous with the common cavity of the body. Under the former class must be included the knob-like processes on the convex surface of many Medusæ containing thread-cells; the papillæ on the generative and stomachal membranes of *Phacellophora*; the thickened margin of the stomachal membrane in *Oceania*; the buccal tentacles of *Mesonema*; the tentacles of the fringe of *Rhizostoma* and *Cephea*, and probably the marginal tentacles of *Thaumantias*. I will proceed to describe some of these more in detail.

30. The papillæ scattered over the generative and stomachal membranes of *Phacellophora* are spherical, and connected with the membrane by a somewhat narrower neck. The substance of this, as well as of the body itself, is made up of large clear cells, but the surface of the body is covered with an immense number of round thread-cells, figs. 20, 20 *a*.

In *Mesonema*, the perpendicular membrane, which depends from the orifice of the central cavity, is prolonged at its edges into a great number of short tentacles. Each of these is composed of an outer wall, in which immense numbers of thread-cells are imbedded, and a central axis made up of large transparent cells. This cellular axis extends for some distance beyond the base of the tentacle into the substance of the membrane, fig. 7.

31. The tentacles of the fringe of *Rhizostoma* and *Cephea* have already been described, fig. 13. The tentacles which beset the generative membrane closely resemble them, and consist of a single membrane, containing many small thread-cells, $\frac{1}{4000}$th of an inch in diameter. Their cavity is filled with a homogeneous substance, sometimes containing nuclei, similar to those of the disc (15.); the inner membrane takes no part in their formation, fig. 30.

32. The marginal tentacles of *Thaumantias* are very similar (fig. 3) to the buccal tentacles of *Mesonema*; they consist of an outer membrane, in which numbers of thread-cells are imbedded, and an inner axis composed of clear cells arranged end to end; they have a peculiarity, which has been already pointed out by Prof. E. Forbes, in being placed above the marginal vesicles instead of being alternate with them, as in the nearly allied genus *Geryonia*; and from this fact, and from their totally different structure, I believe that they have a totally different origin. In *Geryonia* the tentacles belong to the second class—are processes of the circular canal; in *Thaumantias* they are simple processes of the outer foundation membrane, *i. e.* of the substance of the disc. Perhaps this difference in structure among the tentacles may turn out to be a good means of generic distinction among other members of the class.

33. As to the second class of tentacles. Such are the marginal tentacles of *Mesonema*, of *Geryonia* (Will), of *Oceania* and of *Medusa aurita* (Ehrenberg); the tentacles of the under surface of *Phacellophora*, and the interbrachial tentacles of *Cephea*.

34. In the specimens of *Mesonema* I obtained, there were not more than eight tentacles, placed at equal distances round the disc, which had attained their full development. The interval between every two was filled up by a series of bud-like rudimentary tentacles, and marginal corpuscles alternate with them. Each tentacle, in its bud-like rudimentary form, is simply a cæcal process of the circular canal, and has therefore, like it, a double wall and an internal cavity, usually filled with granules in rapid motion, produced by the ciliæ of the inner wall; the outer wall contains large thread-cells. The structure of the adult tentacle is essentially the same, but in the course of its growth it has become divided into a lower filamentous portion and an upper dilated sac, by which it communicates with the circular canal, fig. 8.

The marginal tentacles of *Oceania* resemble these in all points; they are double-walled, communicate freely with the circular canal, and contain an immense number of minute thread-cells in their outer wall, fig. 15.

35. In *Phacellophora* there is no distinct marginal circular canal, but the sixteen radiating canals are very wide and sacciform, and communicate only by anastomosing marginal branches. Eight of the canals are narrower and run to the marginal corpuscles. The alternate eight are very much wider, and their outer, under surface is beset with a curved series of long tentacles, fig. 18. Now the lower wall of the canals is composed of the two "foundation membranes," and the tentacles are simply

prolongations of these membranes; they are therefore double-walled, and contain a cavity continuous with that of the canal. At their upper part they are thicker than below, where their outer membrane is developed into spherical processes containing multitudes of thread-cells and closely resembling those on the generative membrane (30.). The inner cavity becomes obliterated at the lower part of the tentacle, fig. 19.

36. The large interbrachial tentacles of *Cephea* are processes of the branched arms. For the greater part of their length they have the same structure as the arms, *i. e.* consist of a dense, thick, transparent outer substance and an inner membranous wall inclosing a tubular canal; but at the extremity they are thickened, and the outer wall is raised into a number of small pyriform processes, $\frac{1}{100}$th of an inch in diameter, thickly covered with minute spherical thread-cells, $\frac{1}{5000}$th of an inch in diameter. At the same time the central canal becomes branched out into a kind of plexus, which occupies the interior of the enlarged end of the tentacle, fig. 37. These tentacles are 2 inches or more in length and $\frac{1}{15}$th of an inch in thickness, but other smaller tentacles, $\frac{3}{4}$ths of an inch in length by $\frac{1}{30}$th of an inch in diameter, depended from the arched concavity of the brachiferous plate. Their general structure much resembled that of the foregoing, except that the central canal terminated in a blind simple extremity, and that the pyriform bodies extended rather further up the stem.

Beside these there was a third small kind of tentacles, which appeared as small blue points among the stomachs. These were clavate bodies placed without any regular order in the axils between the stomachs, and containing an internal cavity which communicated with the nearest branch of the common canal. A series of pyriform processes, exactly resembling in form those above described, was arranged round their hemispherical extremities. As the individual I observed was a young one (the generative organs not being developed), I conclude that these were young forms of the longer tentacles, fig. 36.

37. *Of the Generative Organs.*—It has been already noticed with regard to the Cryptocarpæ by Will (in *Geryonia*, *Thaumantias*, *Cytæis*, *Polyxenia*), and by Milne-Edwards (in *Æquorea*), that the generative organs are connected with some part of the system of canals, but they do not attempt to define the nature of this connection. I shall endeavour to do this, and to show that the generative organs, both in these and in the Phanerocarpæ and Rhizostomidæ, are always portions more or less developed of the wall of this system; and therefore consist of the two "foundation membranes," in or between which the generative elements, whether ova or spermatozoa, are developed.

38. In *Thaumantias* there are four canals radiating from the centre of the disc, at right angles to one another, and terminating in a circular vessel at the edge of the disc. Near its termination each has a rounded body seated upon it. In most of the specimens I examined this body was distended with ova, and its structure was thereby obscured; but in one instance it was replaced by an elongated, somewhat pyriform

body, which on close examination was found to be simply a dilatation of the canal on which it was seated, having double walls continuous with those of the canal, only much-thickened, and a central cavity communicating freely with that of the canal. This was without doubt a young generative organ, fig. 4.

39. In *Oceania* the canals are very numerous, and radiate from the wide central cavity to the circular vessel at the margin of the disc. In young individuals these canals are narrow and nearly equal throughout, but in adults their inferior wall, for the middle three-fifths of their extent, is greatly enlarged and hangs down in folds or plaits, fig. 15. Under the microscope the wall exhibits an immense number of ova, of all sizes and stages of growth, lying in its substance; and if the edge of a fold be examined, these are seen to be placed between the inner and outer membranes. The inner membrane is thick, and composed of projecting cells with very long ciliæ; the outer membrane is dense, thinner, and much more transparent, figs. 16, 17.

40. This account agrees in its general details very closely with that given by M. Milne-Edwards of the generative organs of *Æquorea**; and I regret the less not having been able to obtain male individuals, as he expressly states that in *Æquorea* the spermatozoa are developed in the same position. There is, however, one discrepancy. M. Edwards states that the generative lamellæ "sont tout à fait distincts de la cavité digestive centrale." I think that on repeating his examination he would find this not to be the case. In *Oceania*, at any rate, I could readily introduce a needle from the stomach into the canals, and show that the lamellæ were mere dilatations of their wall.

In *Polyxenia*, where the canals are very short and the central cavity very large, the ova are situated in the under wall of the cavity, according to Will; but this author enters into no particulars as to the structure of the wall.

41. The generative organs of the Phanerocarpæ have been much investigated. The general result arrived at appears to be, that they are plaited tubular bands attached to the concave wall of a depression existing between the pillars of attachment of the stomachal membrane; that they are altogether separate from the central cavity; that the spermatozoa are developed in pyriform sacs opening externally, and that the ova lie free in the substance of the ovarial band.

42. The structure of the generative organs in *Phacellophora* is as follows:—The voluminous folded and plaited stomachal membrane is attached by four thick pillars to the under surface of the disc. The edges of the pillars are connected by a thin membrane, which is concave externally so as to form a sort of shallow depression or generative cavity, but the central and some of the marginal parts of this membrane are produced into long plaited processes, which hang far out of the cavity, fig. 18. Each process is a sort of sac communicating freely at its attached extremity with the cavity of the stomach, air, &c. passing readily from the one to the other. It is in fact

* Annales des Sciences Naturelles, t. xvi., quoted *verbatim* in Lesson's Histoire Naturelle des Zoophytes Acalèphes.

a sort of eversion of the walls of the stomach, or more properly, of the central cavity. It consists in its upper or attached part of nothing more than the two "foundation membranes," and here they are smooth, but at their lower or free edge they become much plaited, acquire a deeper colour, and exhibit the characteristic generative elements. Short tentacles, similar to those of *Rhizostoma* (31.), are scattered over the inner surface of each process, fig. 21.

43. In the *ovarium*, the two membranes develope between them immense multitudes of ova with a dark granulous yelk and clear germinal vesicle. The ova are attached to the outer surface of the inner membrane, the outer membrane passing quite freely over them, fig. 24.

44. The *testis* is similarly composed of two membranes with an intervening space. The inner membrane is produced into a vast number of thick pyriform sacs, which lie between the two membranes, with their blind ends towards the inner surface of the outer membrane; internally, they open each by a distinct aperture on the free surface of the inner membrane.

45. The contents of the sacs are spermatozoa, and cells in every stage of development towards spermatozoa. These stages are—1. Spherical cells, $\frac{1}{1600}$th of an inch in diameter, filled with smaller nucleated cells (fig. 23 *a*). 2. Cells exactly resembling these included cells but free, and about $\frac{1}{5000}$th of an inch in diameter (*b*). 3. Similar cells, occasionally united into masses with long filiform productions (*c*). 4. Similar cells with a short process in the opposite direction also; these swim about freely and sometimes move their tails (*d*). 5. Perfect spermatozoa with elongated heads ($\frac{1}{1250}$th of an inch), rather larger below than above, where they are not more than $\frac{1}{30.000}$th of an inch in diameter, with very long tails of immeasurable fineness, extending from the larger extremity (*e*). From the existence of these different stages, I conclude that the spermatozoa are formed by the elongation of the secondary cells contained in the large cells first mentioned.

46. I have not been fortunate enough to meet with any description of the generative organs of the Rhizostomidæ except that of these organs in *Cephea* by Will; and as what I have observed differs somewhat from his statements, I will describe those of *Rhizostoma mosaica* somewhat fully.

In this Acalephe, the eight arms which bear the stomachs are inserted into the lower angles of a thick square plate, which I have thence called the "brachiferous plate," fig. 27. From the upper angles of this plate there arise four pillars, of the same structure as the peduncles of the arms, and are inserted into the under surface of the disc rather external to the middle point between its centre and margin. The "brachiferous plate" has no other attachment to the disc, so that it forms the floor of an arched cavity, with four entrances between the suspending pillars of the plate.

The suspending pillars expand at their attachment to the disc into three thickened ribs or crura, two of which are lateral and external, and one central and internal: these are united by a thin membrane. The central crura meet and form a cross under

the centre of the disc; the lateral crura are continuous with the substance of the disc above, and each meets with its fellow external to the centre of the disc, fig. 26. The central crura are united with these and thence with the disc by the thin membrane only. It thence follows that there exists above the central crura and the connecting membrane a wide crucial cavity; into this the canals of the suspending pillars open, and from it radiate the canals which are given off to the circumference of the disc: the crucial cavity then is only a portion of the great system of canals.

47. The external surface of the outer half of the thin uniting membrane (which is composed solely of the two "foundation membranes"), is produced into a vast number of transverse folds of a grayish-green colour in the male, but of a deep orange-red in the female, fig. 26. These give rise to the appearance of a coloured cross shining through when the disc is viewed from above. The inner side of the folds is beset with a series of tentacles, the generative tentacles described above (31), fig. 30. In young specimens, not more than 3 inches in diameter, the generative organs were undeveloped; the outer portion of the thin membrane being as smooth as the inner, but the series of tentacles already existed*.

In adults the margins of the folds contain the spermatozoa in the male, the ova in the female.

48. In the *ovarium* the ova lie between the inner and outer foundation membranes, which are both ciliated on their free surfaces. The ova are attached to the outer surface of the inner membrane by a kind of pedicle, which expands into the thick vitellary (?) membrane; this chorionic coat is distinctly cellular in middle-sized ova, in larger ones it is thicker and homogeneous. If the inner surface of the inner membrane be examined, a depression will be seen opposite each ovum: the yelk of the ova is granulous and of a bright orange colour. The germinal vesicle is clear and thin-walled, and is $\frac{1}{700}$th of an inch in diameter; the germinal spot is a thick-walled cell $\frac{1}{3300}$th of an inch in diameter, fig. 32.

49. So far as the structure of the inner and outer membranes is concerned, the *testis* resembles the *ovary*. But the spermatozoa are contained in ovoid or pyriform, thick-walled sacs, about $\frac{1}{80}$th of an inch in long diameter placed between the two, fig. 31. In one individual the sperm-sacs were more ovoid in shape, and did not appear to have any particular attachment to either membrane, but in the rest they were all connected with the inner membrane, and when its inner surface was turned towards the eye, the

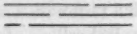
* It appears to me that M. Milne-Edwards must have had a young individual of *Rhizostoma* before him, when he says (Observations sur la Structure de la Méduse Marsupiale), "Nor does the plaited membrane, which forms a sort of partition between the central and the four lateral cavities, appear to be an organ of reproduction. If we examine one of these membranes superficially with the naked eye, we see towards its upper part a kind of woollen fringe, which at first sight might be taken for a series of glandular sacs, but by the aid of the microscope it is found that this appearance is due in fact to a multitude of suckers (*suçoirs*), having the greatest similarity in form to those appendages which are observable in certain parts of the body of different Zoophytes, such as *Vitella*, *Actinia*, &c. From this it would appear that these membranes are much more fitted for absorption or respiration, as is the opinion of M. Eysenhardt, than for the formation of ova."

openings of the sacs could be perceived: the sacs were filled with spermatozoa with triangular heads, about $\frac{1}{10,000}$th of an inch in diameter, and very long, fine, delicate tails, fig. 31 *a*. The course of their development appeared to be as in *Phacellophora*.

50. *Rhizostoma* and *Phacellophora* then agree in having the spermatozoa developed in sacs connected with the inner "foundation membrane" and opening internally. It would appear from this that the exit for the spermatozoa is through the mouth of the animals, though this course in *Rhizostoma* would certainly be a rather circuitous one.

51. The individual of *Cephea* (*C. ocellata*) which I examined resembled, with regard to the generative organs, a young *Rhizostoma*. The line of generative tentacles was present, but the generative organs were undeveloped. According to Will, the structure of the testis in *Cephea Wagneri* closely resembles that of *Rhizostoma*. He says that there is a cavity under the disc into which the canals of the arms and disc open; that the floor of this cavity is formed by a thin membrane covered with fine tentacular appendages, and that the band-like testes are attached to the under free surface of the membrane; they consist of pyriform sacs (*flaschenförmigen Drüschen*) closely applied together, and each opening independently below. The spermatozoa are elongated and cylindrical, and have a very long, fine appendage.

52. With regard to the *muscular system* of the Medusæ, such observations as I have made lead me to believe that the muscular fibres are always developed in the outer "foundation membrane." In *Rhizostoma* the muscular fibres of the under surface of the disc are flat, pale, and from $\frac{1}{1250}$th to $\frac{1}{600}$th of an inch in diameter. They run parallel to one another, but the lines of separation between them are not continuous throughout, but thus: each fibre is made up of very small and indistinct fibrils, which are transversely striated, the striation being most distinct at the edge of the fibres.



53. I have not observed any indubitable trace of a *nervous system* in the Medusæ.

54. Will has described a blood-vascular system, consisting of a system of canals inclosing the water canals and containing a distinct fluid with cells floating in it. I have paid particular attention to this point in all my examinations of the Medusæ, but notwithstanding that I have had species of the very same genera (*Cydippe*, *Cephea*, *Thaumantias*) under my hands, I have never observed any trace of it. I am at a loss even to understand what he means, unless, as I strongly suspect, he has taken the outer foundation membrane, which occasionally is thick and distinct from the inner, especially about the circular marginal canal, for the walls of a distinct vessel. Even if this be the case, what are the blood-corpuscles?

55. The *thread-cells* resemble in all respects those of the Diphydæ, which I have described elsewhere, consisting of a delicate outer cell inclosing another thick-walled cell, with a spiral filament of greater or less length, coiled up in its interior and capable of protrusion on pressure.

Section II.—*Of the Affinities of the Medusæ.*

56. Certain general conclusions are deducible from the facts stated in the preceding section. It would appear,—

1st. That a Medusa consists essentially of two membranes inclosing a variously-shaped cavity, inasmuch as its various organs are so composed (7, 8, 14, 21, 22, 29, 33, 38, 39, &c.).

2ndly. That the generative organs are external, being variously developed processes of the two membranes (38, 39, 42, 48, 49); and

3rdly. That the peculiar organs called thread-cells are universally present (7, 15, 31, 32).

Now in these particulars the Medusæ present a striking resemblance to certain other families of Zoophytes. These are the Hydroid and Sertularian Polypes, the Physophoridæ and Diphydæ, with all of which the same three propositions hold good*.

57. But in order to demonstrate that a real affinity exists among different classes of animals, it is not sufficient merely to point out that certain similarities and analogies exist among them; it must be shown that they are constructed upon the same anatomical type, that, in fact, their organs are homologous.

Now the organs of two animals or families of animals are homologous when their structure is identical, or when the differences between them may be accounted for by the simple laws of growth. When the organs differ considerably, their homology may be determined in two ways, either—1, by tracing back the course of development of the two until we arrive by similar stages at the same point; or, 2, by interpolating between the two a series of forms derived from other animals allied to both, the difference between each term of the series being such only as can be accounted for by the laws of growth. The latter method is that which has been generally employed under the name of *Comparative Anatomy*, the former being hardly applicable to any but the lower classes of animals. Both methods may be made use of in investigating the homologies of the Medusæ†.

58. A complete identity of structure connects the "foundation membranes" of

* "Les parois du tube nutritif sont formées d'une double membrane toujours rondée intimement dans cette partie du polype, l'externe répond aux téguments; l'interne est une continuation de la membrane digestive de la capacité alimentaire."—Cuvier, Org. de Génération des Zoophytes, Leçons d'Anat. Comp. t. viii. 2nd edit.

I have elsewhere pointed out that the same circumstance obtains among the Diphydæ and Physophoridæ.

That the generative organs are external in the Sertularian and Hydroid Polypes has been long known. Milne-Edwards has shown that they have a similar position in one of the Physophoridæ (*Apolemia*). I have observed it myself in the Diphydæ.

The presence of the thread-cells has been determined by Will in the Diphydæ, by Milne-Edwards in *Apolemia*, by myself (only ??) in *Physalia*, *Physophora*, *Athorybia* and other Physophoridæ, and in the Sertularian Polypes.

† The above definitions may be thought needless and even trite, but the establishment of affinities among animals has been so often a mere exercise of the imagination, that I may be pardoned for pointing out the guiding principles which I have followed, and by which I would wish to be judged.

the Medusæ with the corresponding organs in the rest of the series; and it is curious to remark, that throughout, the outer and inner membranes appear to bear the same physiological relation to one another as do the serous and mucous layers of the germ; the outer becoming developed into the muscular system and giving rise to the organs of offence and defence; the inner, on the other hand, appearing to be more closely subservient to the purposes of nutrition and generation.

59. The structure of the stomach in the Medusæ is in general identical with that of the same organ in the rest of the series. The Rhizostomidæ offer an apparent difficulty, but it appears to me that the marginal folds in them answer to the stomachal membrane of the Monostome Medusæ; the apertures to the inner orifice of their stomach, and the common canal to their "common cavity." Just as in a polygastric Diphyes the common tube answers to the chamber into which the stomach of a monogastric Diphyes opens; and in *Cephea Wagneri* (Will) these resemblances are still more striking. He says that each cotyledon "has at its apex a small round opening, the mouth, which leads to an ovate cavity, occupying the whole interior of the cotyledon. I consider this as the proper digestive or stomachal cavity, and believe that the cotyledons have the same relation to the vessels as the so-called suckers (*Sangröhren*) of the Diphydæ to the common tube (*Saftröhre*)*."

60. The disc of a Medusa is represented by the natatorial organ among the Diphydæ and Physophoridæ. Take for instance the disc of *Oceania* or *Cytæis*. It is here a more or less bell-shaped body, traversed by radiating canals, lined by a distinct membrane, united by a circular canal at the margin. In the centre the radiating canals communicate freely with the chamber into which the stomach opens. The inner margin of the disc is provided with a delicate, circular, valvate membrane. The same description applies, word for word, to the natatorial organs of the Diphydæ and Physophoridæ; the only difference being, that in the latter the stomach is *outside* the cavity (fig. 47) of the organ, instead of being, as in the Medusæ, suspended from its centre *inside*, fig. 49. And even if the different texture of the two organs should give rise to any doubt, the genus *Rosacea*, in which the natatorial organ is perfectly soft and gelatinous, furnishes the needful intermediate form.

61. The disc of the Medusæ has no representative among the Hydræ and Sertulariadæ. The cell of the Sertularian Polype rather resembles the "bract" of the Diphydæ than the "natatorial organ" in its structure and function, and in this manner the Diphydæ form a connecting link between the Medusæ and the Physophoridæ.

62. Of the two kinds of tentacles of the Medusæ, the first is represented, in the Physophoridæ and Diphydæ, by the thickenings, richly beset with thread-cells, that frequently occur in the lip of the stomach; in the Sertularian Polypes (*Plumularia*, *Campanularia*) by the tentacles of the margin of the mouth, which precisely resemble the tentacles of the fringe of *Rhizostoma*, or the marginal tentacles of *Thaumantias*,

* Horæ Tergutinæ, p. 60.

in being composed of a single membrane covered with thread-cells, and having a cellular axis.

63. The second kind of tentacle is homologous with the prehensile organs of the Diphydæ and Physophoridæ with the peculiar clavate processes of *Plumularia*, and so far as I can judge from descriptions of their structure, with the tentacles of *Hydra*.

All the organs here mentioned commence their development as bud-like processes of the two primary membranes, elongating and attaining the forms peculiar to their perfect state as they grow older. The tentacles of the Medusæ are usually developed (as in most Monostomatæ) from the circular vessel of the disc, sometimes (*Phacellophora*)from the diverging canals, sometimes, finally, from the neck of the stomach *Lymnorea*, *Javonia*). The prehensile organs of the Physophoridæ also have considerable variety in position. In *Porpita*, *Vitella*, *Angela* (?), they are developed from the margin of the float; in *Physophora* and many others from the base or the pedicle of the stomach. The prehensile organs of the Diphydæ are always developed either from the base or the pedicle of the stomach. The peculiar clavate organs of *Plumularia* are developed from the common tube independently of the stomach.

64. The adult forms of these organs have all the same structure, being composed of two membranes, with a vast number of thread-cells of larger or smaller size, seated in the substance of the outer membrane or between the inner and the outer.

65. The "clavate organs" of *Plumularia* deserve especial notice, as I am not aware that they have been hitherto described, and as they exemplify in a very beautiful manner the "unity of organization" manifest among these families.

I have found them in two species of *Plumularia* obtained by the dredge at Port Curtis; they were of two kinds, the one attached to the cell of the polype, the other to the pedicle of the ovary, figs. 43, 44, 45. In each species there were three processes of the former kind, two above proceeding from near that edge of the aperture which is towards the stem, the other below from the front part of the base of the cell; they were conical in the one species, club-shaped and articulated in the other, and consisted of an external horny membrane open at the apex, and an internal delicate membrane inclosing a cavity, all these being continuous with the corresponding parts of the stem. At the apex of each, and capable of being pressed through the aperture, lay a number of thread-cells; with moderate pressure the threads only of these organs were pressed out.

I found the second kind of organ in the species with conical processes. It consisted of a stem proceeding from the pedicle of the ovary, bearing a series of conical bodies having the same constitution as those just described, fig. 45. The perfect resemblance between these and the prehensile organs of the Diphydæ cannot be overlooked.

66. The structure of the generative organs is still more instructive. In the Medusæ I have endeavoured to show that there are always processes of the two

foundation membranes, the generative elements being developed between them, figs. 1 *a*, 11 *a*, 18 *a*, 26 *a*.

67. In the Diphydæ (and as I have good reason for believing in the Physophoridæ also) the generative organ commences as a simple process of the common tube (fig. 39 *a*), and undergoing great changes of form in the course of its development (*b*, *c*), it becomes at last exactly similar to an ordinary natatorial organ with a sac composed of two membranes suspended from its centre, fig. 39. In external form it greatly resembles such a *Medusa* as *Cytæis*, and this resemblance is much heightened when, as in some cases, it becomes detached and swims freely about, fig. 41. The ova or spermatozoa, as the case may be, are developed between the two membranes of the sac, the inner of which at any rate is a continuation of the inner membrane of the common tube, fig. 39.

68. The ovarium of the *Plumularia* above mentioned (65.), commences as a dilatation of the apex of its pedicel, which again is a process of the common stem. It then becomes lenticular with a horny outer wall, glassy and transparent externally, but internally coloured by pigment masses. Internally it has an oval cavity communicating with that of the stem and lined by a distinct membrane, fig. 45. Between the two membranes is a thick layer of ova, more or less oval in shape, and about $\frac{1}{350}$th of an inch in diameter, with a germinal spot about $\frac{1}{2400}$th of an inch in diameter, seated in the middle of a clear space about twice that size, which doubtless represents the germinal vesicle.

69. The account given by Löwen of the generative organs of *Campanularia* differs considerably from the foregoing. After all however his "female polypes" may be nothing more than ovaria similar to those of *Diphyes* or *Coryne*, but having the production of tentacles from the margin carried to a greater extent than in the latter. If this be a correct explanation, the idea promulgated by Steenstrup, that there is an "alternation of generations" among the Sertularian Polypes, must be given up.

70. In *Hydra**, the ova are developed in similar processes of the lower part of the body. But among the Hydroid Polypes the ovaries of *Coryne*, *Syncorine* and *Corymorpha*, as described by Sars, Löwen and Steenstrup, are most interesting. They commence as tubercles of the stem, afterwards become bodies, precisely resembling the ovaria of the Diphydæ, and finally (fig. 42) detaching themselves develope regular tentacles from their margin. The ova are formed between the two membranes of the inner sac†.

* M. Dujardin, Annales des Sciences Naturelles, November 1845, states on the authority of Ehrenberg, Corda and Laurent, that the ova of the freshwater Polype are "produits dans l'épaisseur même du tissu sans ovarie ni ovule préalable."

† "The axis of the bell is occupied by a membranous sac, which is a prolongation of the nutritive canal, and answers to the alimentary cavity of the alimentary Polypes. The ova are developed in regular series in the interval between this alimentary capsule and the parietes of the outer sac, in an intermediate membranous sac, distinguished by its yellowish brown colour."—Cuvier, Leçons d'Anat. Comparée, t. viii. Organs de Génération des Zoophytes, p. 860. See also Duvernoy, Annales des Sciences Naturelles for November 1845.

71. What has now been advanced will perhaps be deemed evidence sufficient to demonstrate,—1st, that the organs of these various families are traceable back to the same point in the way of development; or 2ndly, when this cannot be done, that they are connected by natural gradations with organs which are so traceable, in which case, according to the principles advanced in 57, the various organs are homologous, and the families have a real affinity to one another and should form one group.

72. Perhaps the view that I have taken will be more clear if I throw it into a tabular form, placing opposite one another those organs in the different families, for the homologies of which there is, I think, sufficient evidence, thus:—

Stomachs identical in Structure throughout.

Medusæ.	*Physophoridæ.*	*Diphydæ.*	*Sertularidæ.*	*Hydræ.*
Disc	Natatorial organ	Natatorial organ.		
Canals	Canals of natatorial organ	Canals of natatorial organ.		
Common cavity / Canals of branches (*Rhiz.*)	Common tube	Sacculus and common tube.	Cavity of stem.	
		Bract	Polype-cell.	
Tentacles, 1	Thickened edge of stomach		Oval tentacles.	
2	Prehensile organs		Clavate organs	Tentacles (?).
Generative organs	Generative sac		Generative organ	Generative organ.
	Natatorial organ of generative sac			Natatorial organs (Coryne).
Marginal vesicle	?	?	?	?

73. It appears then that these five families are by no means so distinct as has hitherto been supposed, but that they are members of one great group, organized upon one simple and uniform plan, and even in their most complex and aberrant forms, reducible to the same type. And I may add, finally, that on this theory it is by no means difficult to account for the remarkable forms presented by the Medusæ in their young state. The Medusæ are the most perfect, the most *individualized* animals of the series, and it is only in accordance with what very generally obtains in the animal kingdom if in their early condition they approximate towards the simplest forms of the group to which they belong.

74. I have purposely avoided all mention of the Beroidæ in the course of the present paper, although they have many remarkable resemblances to the animals of which it treats: still such observations as I have been enabled to make upon them have led me to the belief, that they do not so much form a part of the present group as a link between it and the Anthozoic Polypes. But I hope to return to this point upon some future occasion.

Sydney, April 24th, 1848.

*** Since the above was written I have had an opportunity (by the kindness of W. MacLeay, Esq., to whose advice I am much indebted) of reading M. Dujardin's "Mémoires sur le Développement des Méduses et des Polypes Hydraires," contained

in the Annales des Sciences Naturelles for November 1845. This author has, as it appears to me, been misled by the great analogy between the structure of a Medusa and that of the generative organ of a Coryniform Polype, into taking the detached organ of the Polype for a real Medusa. He does not hesitate to say that the Claviform Polypes are "only a first stage of development of the Acalephæ." He hints that each clavate Polype has its corresponding Acalephe, and he does not hesitate to give the latter distinct names as independent genera (*Sthenyo*, *Cladonema*).

Here, as in many other instances, the study of the Diphydæ throws light upon the matter. The detached free-swimming testis or ovary of a species of *Sphenia* has just as much claim to a distinct generic name as has *Sthenyo* or *Cladonema*, and yet in what respect does this differ from the persistent ovary of *Eudoxia*, which surely is an organ, and nothing but an organ?

Would it not be as reasonable to give a distinct name to NEEDHAM's sperm-sacs because they exhibit certain independent motions external to the body of the Cephalopod?

The point is of consequence, because it is anything but desirable that *true polypes* with *medusiform* generative organs should be confounded with the *Polypiform larvæ* of true Medusæ.

DESCRIPTION OF THE PLATES.

*** In all the sectional diagrams the letters have the same meaning, viz. *m*. Stomach. *n*. Common cavity. *o*. Canals. *p*. Generative organ. *q*. Natatorial organ. *t*. Tentacle. *u*. Marginal vesicle. *x*. Outer membrane. *x'*. Bract. *x''*. Valvular membrane.

PLATE XXXVII.

Thaumantias ——?

Fig. 1. Disc seen from above.
Fig. 1 *a*. Imaginary vertical section.
Fig. 2. Opening of the stomach into the canals seen from above.
Fig. 3. Marginal tentacles.
Fig. 4. Young generative organ.

Mesonema?

Fig. 5. Lateral view of the animal.
Fig. 5 *a*. Vertical section.
Fig. 6. View of a segment of the disc; under surface.
a. Buccal tentacles.
b. Canals.
c. Marginal membrane (20.).

Fig. 7. A single buccal tentacle much magnified.
Fig. 8. A portion of the marginal canal with a tentacle and two marginal corpuscles.
Fig. 9. Portion of the marginal canal (*a*) with young tentacle (*b*), and a marginal vesicle containing two corpuscles, each inclosed within a delicate cell-wall.
Fig. 10. A marginal vesicle highly magnified; the two corpuscles do not appear to have attained their full development, as they refract less, and the cell appears more opake.

Oceania ——?

Fig. 11. Lateral view of the animal.
Fig. 11 *a*. Vertical section.
Fig. 12. Part of the under surface of the disc.
a. Marginal membrane.
b. Canals and generative organs.
c. Common cavity.
Fig. 13. Part of the membrane surrounding the mouth.
Fig. 14. The edge of this much magnified.
Fig. 15. Part of the margin of the disc much enlarged.
a. Marginal membrane.
b. Canal and generative organs.
c. Tentacle.
d. Marginal corpuscles.
e. Circular canal.
Fig. 16. Portion of the ovarium so folded as to have its inner membrane (*a*) outwards.
Fig. 17. Sectional view of the ovarium.
a. Inner membrane.
b. Outer membrane.
c. Ovum.
d. Germinal vesicle.
e. Germinal spot.

PLATE XXXVIII.

Phacellophora ——?

Fig. 18. View of a segment of the under surface.
a. Marginal vesicles.
b. Tentacles in this individual very much shorter than usual.
c. Ovary or testis.
d. Buccal membrane.
Fig. 18 *a*. Vertical section.

Fig. 19. Tentacle.
Fig. 20. Portion of the buccal membrane.
Fig. 20 *a*. Round processes containing thread-cells scattered over its outer surface.
Fig. 21. Portion of the testis.
a. Generative tentacles.
Fig. 22. Sectional view of part of the testis.
a. Outer membrane.
b. Sperm-sacs.
c. Inner membrane.
Fig. 23. Stages of development of the spermatozoa (45.).
Fig. 24. Ovarium.
a. Outer membrane.
b. Ova.
c. Inner membrane.
Fig. 25. Marginal vesicle from the under surface.
a. Dilatation of the canal.
Fig. 25 *a*. Marginal vesicle and pedicle very much enlarged.

Rhizostoma mosaica.

Fig. 26. View of the under surface of the disc, the brachiferous plate being cut away.
a. Marginal vesicles.
b. Cut extremity of the suspending pillar of the brachiferous plate.
c. Central crura.
d. Lateral crura.
e. Generative folds.
f. Connecting membrane.
Fig. 26 *a*. Vertical section of the Rhizostoma.
Fig. 27. Side view of the brachiferous plate detached.

PLATE XXXIX.

Rhizostoma mosaica.

Fig. 28. Extremity of one of the ultimate ramifications of the arms.
a. Thick substance of the outer membrane.
b. The central common canal.
c. The lateral canals leading to the apertures.
d. The fringes.
Fig. 29. Lateral view of one of the apertures much magnified.
a. Thick outer membrane.
b. Inner membrane.
c. Lateral canal.
d. Tentacles.

Fig. 30. Portion of the testis slightly magnified.
a. Generative tentacles.
Fig. 31. Sectional view of testis much magnified.
a. Outer membrane.
b. Inner membrane.
c. Sperm-sacs.
Fig. 31 *a*. Spermatozoa.
Fig. 32. Ovarium.
a. Outer membrane.
b. Inner membrane.
c. Ova.
Fig. 33. Marginal vesicle, upper surface.
a a. Lobes connected by the arched membrane, *b*.
c. Cæca of the canal *f*.
d. Vesicle on its pedicle.
e. Cordate depression.
Fig. 34. Marginal vesicle from below, much magnified.
a a. Lobes.
b. Inferior connecting membrane.
c. Cæca.
d. Elevation of the outer membrane.
e. Muscular fibres.

Cephea ocellata.

Fig. 35. An aperture surrounded by its membrane.
Fig. 36. Portion of the extremity of an arm, with a young interbrachial tentacle (*a*).
Fig. 37. Extremity of one of the large interbrachial tentacles.

Diphydæ.

Fig. 38. Vertical section of a monogastric Diphyes.
Fig 39. Attached ovarium.
a. Natatorial organ.
b. Ovisac.
Fig. 39 *a*. Youngest stage of ovarium.
a. Simple process of the common cavity.
b, *c*. Ovaria further advanced.
Fig. 40. Prehensile organ.
a, *b*. Early stages.
Fig. 41. Free-swimming ovarium.
a. Natatorial organ.
b. Ovisac.

Fig. 42. Free-swimming ovarium of Coryne (from Steenstrup) to compare with fig. 41.

Sertularidæ.

Fig. 43. Cell of *Plumularia* ——?
a. Peculiar clavate organs.
b. Large thread-cells.
Fig. 44. Cell of another Plumularia, letters as before.
Fig. 45. Ovarium of fig. 43.
a. Organs containing thread-cells similar to fig. 43 *a*.
b. Ova.
Fig. 46. Section of Plumularia.
Fig. 47. Section of Polygastric Diphyes.
Fig. 48. Section of Rhizostoma.
Fig. 49. Section of Monostome Medusa.

XXIII. *On the Microscopic Structure of the Scales and Dermal Teeth of some Ganoid and Placoid Fish. By* W. C. Williamson, *Esq. Communicated by Dr.* Lankester, *F.R.S.*

Received June 1,—Read June 21, 1849.

At an early period after the invention of the microscope, the structure of the scales of fish attracted the notice of observers. At that time, little was known respecting the important group to which M. Agassiz has since applied the term "Ganoid;" their attention was consequently directed to the other subdivisions, and especially to the "Cycloid" forms; the object aimed at being to account for the concentric circles on the surface of the scale, which had been noticed by Barellus in 1656*. Hooke touches upon them in his 'Micographia,' published in 1667. Five years later, the accurate Leeuwenhoek submitted them to a careful examination, and concluded, according to M. Mandl, "Qu'il se forme chaque année, une nouvelle écaille au dessous de l'ancienne, qui la déborde, de sort que l'on aperçoit sur l'écaille le bord de l'ancienne écaille, et qu'on peut ainsi en comptant dans une section transversale le nombre des couches, déterminer l'âge du poisson et le nombre d'écailles accessoires, qui forment l'écaille entière†."

During a century subsequent to this discovery, but little new light appears to have been thrown upon the subject; and though Mandl, in the memoir just quoted, cites the names of Reaumur, Roberg, Petit, Schæffer, Baster, Ledermuller and Brousonnet, as having directed their attention to it, they appear to have left it pretty much where they found it.

During the present century, Heusinger, Kuntzmann, Ehrenberg, Agassiz, Mandl and Owen have in succession investigated the matter, but the labours of the three last alone require a more special notice.

At an early period in the progress of the colossal labours of M. Agassiz, he was struck with the vast importance of studying the scales of fish, and, as is well known, ultimately made their variations the basis of his classification. In the fourth chapter of his large work, headed "Dermatologie et en particulier des écailles des poissons‡," he enters very elaborately into the structure of the skin and scales, with the relationship of the one to the other; and he especially seeks to illustrate, what was then a new topic, the structure of the scales of many of his "Ganoid" fish, pointing out their enamelled (*émaillé*) surface, the large development of a dentine-like substance in the

* Petrus. Observationum Microscopicarum Centuria.

† Annales des Seiences Naturelles, vol. ii. p. 338.

‡ Poissons Fossiles, vol. i. p. 61.

upper part of many of them, as well as the existence of a true osseous tissue with lacunæ, and even Haversian canals in the lower portions of some scales. The usual existence of a structure more or less laminated, is accurately noticed; and he especially points out the close and striking resemblance between some of these organisms and the teeth of fishes; one general result of his observations being a conviction that these scales were formed by the gradual and successive deposition of layers of osseous tissue, a practical revival of the opinion first promulgated by LEEUWENHOEK, nearly two centuries ago. These views were opposed by M. MANDL, in a memoir* in which he endeavoured to account for the structure of cycloid scales especially in a totally different way. This publication elicited from M. AGASSIZ an effective reply, in which he gives the following valuable summary of his views:—"J'envisage l'écaille du poisson comme une sécrétion épidermoidale, absolument analogue à celle des ongles et autres de même nature, qui s'observent chez les animaux supérieures. Comme les ongles, elles se composent de lamelles très fines d'une substance cornée, superposées dans l'ordre de leur formation. L'organe sécréteur est la poche épidermoidale dans laquelle elles sont enfoncées par leurs bords antérieurs. La portion de l'écaille recouverte par le feuillet supérieur de cette poche est plus ou moins considérable; le feuillet inférieur, au contraire, recouvre presque toute la face interne de l'écaille, excepté dans quelques cténoides, où la face inférieure des dentelures est libre. Les lamelles nouvellement formées, sont plus molles, mais de même composition que les plus anciennes. La poche grandit à mesure que l'écaille dévelope, de sorte que les lames, nouvellement déposées, sont toujours plus grandes que les anciennes. Les stries concentriques de la poche sont dues à cette circonstance, en ce sens que le bord de chaque nouvelle lame occasionne par le pression qu'il exerce sur la poche un pli, ou plutôt une impression très légère qui correspond naturellement au bord de cette lame. Les lignes concentriques des écailles sont le reflet des bords des lamelles superposées. Aussi sont elles plus nombreuses chez les poissons âgés que chez les jeunes†."

In the body of his large work‡, M. AGASSIZ introduces descriptions of the microscopic structure of some ganoid scales, especially of those of the recent *Lepidosteus osseus* and *Polypterus*, as well as of the *Lepidotus gigas* and *L. unguiculatus*: and in the volume on the fossil fish of the old red sandstone, he gives the result of some very careful examinations of the scales belonging to many of the interesting genera from that group of deposits.

Professor OWEN has slightly touched upon the subject in his recently published lectures§, where he observes, "In the *Lepidosteus*, the scales defend the body in close-set oblique rows; are thick, completely ossified, and with an exterior hard, shining, enamel-like layer, having the microscopic structure of the hard dentine of sharks' teeth; the subjacent osseous part exhibits the radiated corpuscles. I described

* Annales des Sciences Naturelles, vol. ii. † Ibid. vol. xiv. p. 108. ‡ Poissons Fossiles.

§ Lectures on the Comparative Anatomy and Physiology of the Vertebrate Animals, 1846, p. 140.

the organic structure of the so-called ganoid scale-bones in 1840, both in recent and extinct fishes, showing that it militated against the theory of the development by successive deposition of layers being applied, at least to ganoid scales." A reference is made to the 'Odontography,' p. 15, where I find the following foot-note:—"A very close analogy exists between the dermal bony tubercles and spines of the cartilaginous fishes and their teeth. The system of minute parallel tubes, with their branches and anastomoses in the thick scales of the extinct *Lepidotus*, is as complicated as in many teeth, and equally militates against the theory of transudation of layers being applied, at least to ganoid scales." The new facts brought forward by Professor Owen are some observations on the opercular and other bones of the Carp and Gold-fish, from which he concludes that the opercular bones are not modified dermal scales; the remaining illustrations had already been developed by M. Agassiz, both in his descriptions and by his drawings*.

The last writer who has alluded to the subject is Mr. E. Queketт. His observations however† are confined principally to the forms of the lacunæ found in the scales of *Lepidosteus osseus* and *Callichthys*. Such was the state of this subject when I entered upon a further series of observations. The difficulty which I had experienced in identifying what I had seen of the structure and development of human bone, with the descriptions given by Muller, Tomes, Todd, Bowman and others, led me to take up the examination of these forms of osseous tissue, in the hope that they would throw some additional light on the question. The wide difference also which existed between the views of Owen and Agassiz as to their mode of growth, rendered a further inquiry into the development of the scales necessary. I hope and believe that the facts about to be brought forward will at least be found sufficiently conclusive to settle the question; by showing that, whilst the scales are formed, as originally stated by M. Agassiz, by the apposition of successive layers, these layers are not generated by any process of secretion, but by the calcification of an organized basis, resembling that of bones and teeth, as asserted by Professor Owen.

Though M. Agassiz has already investigated the structure of the scales of *Lepidosteus osseus* and *Polypterus niloticus*‡, the importance of an accurate knowledge of these recent types of the Sauroid group of fish, in contributing to the illustration of the fossil species, led me again to subject the scales of *Lepidosteus osseus* to a careful examination: whilst the result has been confirmatory of most of the observations of M. Agassiz, it has also revealed one or two points which have escaped his eye, but which are of importance.

Plate XL. fig. 1 represents a vertico-longitudinal section of a scale of *Lepidosteus osseus*. From *a* to *b* represents the anterior portion of the scale, which, when *in situ*, is imbedded in the skin, and covered by the posterior overlapping margin of the antecedent scale. *c* represents the posterior margin. The whole structure is composed of

* Poissons Fossiles, vol. i. p. 73 tab. H.; vol. ii. tab. G.

† Transactions of the Microscopical Society of London, vol. ii. part 2.

‡ Vol. ii. part 2, p. 5 *et seq.*

exceedingly thin lamellæ*, which are folded back upon themselves at the edges of the scale, the lowermost ones overlapping those which rested upon them, and covering them over to a considerable extent. This is especially the case at the anterior portion of the scale, but also exists to a considerable extent at the lateral margins, or those which are parallel to the mesial line. Fig. 2 represents the section of the half of a scale taken at right angles to this line, and where along the whole of the upper margin we see this duplicature of the lamellæ towards the centre of the scale. It is also seen to a slight extent along its anterior border.

Between these parallel lamellæ are multitudes of lacunæ with radiating canaliculi. These lacunæ M. Agassiz designates by the almost exploded term of "bone-corpuscles." They appear to be cavities between two contiguous lamellæ, in the plane of which the canaliculi are spread out, but without appearing to perforate either of them. I have not attempted to represent them in the Plate, as they would have rendered its details confused and indefinite.

Along the upper margin of the section, especially at certain points, as at fig. 2 *a*, the terminations of several of these lamellæ combine to form a tooth-like projection, each of which corresponds with more clearly marked divisions existing in the section of the scale, and which I have distinguished as constituting the *Laminæ*; were not these surmounted by ganoin†, they would have formed elevated ridges on the surface of the scale.

Arranged nearly at right angles to the lamellæ, are a number of narrow tubes, figs. 1 *f* and 2 *b*. These penetrate from the exterior to the interior of the scale, and have usually a diameter of about $\frac{1}{8000}$th of an inch. They are of nearly uniform width, somewhat undulating, and though usually simple, sometimes divide into two or three branches. A few of them terminate in the inferior and middle lamellæ of the scale, but in the central and anterior regions, they are generally prolonged until reaching within a short distance from the upper surface. At the anterior part, and towards the lateral margins, they terminate in the region where the successive lamellæ turn back upon themselves, figs. 1 *c* and 2 *c*. Thus the scale is divided into two portions; a superior one, in which all these tubes, preserving their rectangular position in relation to the lamellæ through which they pass, enter from the upper surface, and an inferior and far more extensively developed one, which is wholly supplied from below. At their termination these tubes generally divide into two or three short branches. They were seen by M. Agassiz, but on some points our observations differ. He says

* I have employed the terms lamellæ and laminæ throughout the memoir to represent two distinct appearances. The former I have applied to the ultimate thin layers into which the use of high magnifying powers enables us to subdivide the thickness of the scale. By the latter I have distinguished certain more conspicuous subdivisions, each consisting of numerous lamellæ, and each of which is thought by M. Agassiz to be the result of one year's growth.

† I have preferred employing the term Ganoin, to represent the hyaline substance covering over many of these scales, in preference to that of Enamel. It is different in its character from the prismatic structure covering the dentine of the teeth of mammals, and the employment of one term to designate both leads to error.

that "ces tubes vont mourir à la limite de la substance osseuse, et jamais on ne les voit entrer dans la couche émaillée." Sometimes however they do penetrate the layers of ganoin, as at fig. 2 *d*, where the tubes perforate several of its laminæ, having evidently once passed through them to open upon the external surface of the scale, and having only been closed up by the subsequent addition of new laminæ of ganoin. In the *Lepidosteus* their branching extremity always terminates in the structure *below* the ganoin and never in it.

M. Agassiz thinks that these tubes have not served as channels for the conveyance of nutriment to the interior of the scale, but as depôts of calcareous matter. "Je serais plutôt disposé à croire que ces tubes ont une destination analogue aux corpuscules osseux et des tubes dentaires, savoir, de servir de dépôts de matière calcaire." With this conclusion I cannot agree; the tubes appear to me to be open canals in the hard tissue of the scale. Besides which, most modern physiologists entertain a different view, both of the lacunæ of bone and the dental tubes of teeth, to that held by the Swiss philosopher.

The real nature and use of these tubes is a point about which I am dubious. In *Lepidosteus osseus* we only see their partial development, but in some of the fossil species, hereafter to be described, we shall find them assuming a new aspect.

In addition to these, there exists an extensive development of a second set of tubes (fig. 2 *e*), which are still more minute, but which also radiate from the outer surface to the inner portions of the scale. They penetrate the lamellæ in a much more oblique direction, crossing the larger tubes at an acute angle, verging as they do so, from the outer border, towards the centre of the scale. They do not ascend directly, but in the manner of a succession of steps, having a constant tendency to be spread out for a short space between the lamellæ, and then obliquely penetrating those above them, they repeat the same process. They are very much branched. This system of tubes appears to have escaped the notice of M. Agassiz, and I have not seen any reference to their existence in *Lepidosteus* by subsequent writers. We shall find, as we proceed, that in one form or another there are very few ganoid scales in which they are not extensively developed, and as we shall often have to refer to them, I should propose to distinguish them by applying to them the term *Lepidine*. Though not the homologues of dentine, they appear to fulfill a similar function in the scales to that which the dentine tubes do in the teeth, though they are often limited in their distribution to particular portions of the true scale tissue, which is not the case with dentine. I suspect that they have much more to do with the general nutrition of the scale, than the more parallel and larger tubes previously described: we shall afterwards find that the latter only exist in a few groups of fish, and that in them the ultimate distribution of these tubes is mainly restricted to particular regions of the scale. But the lepidine tubes are very different. I have seen few scales in which I could not demonstrate their existence, generally crowded together in vast numbers, and giving off numerous minute branches as they proceed, to each succeeding lamella, even

when their distribution is confined, as we shall occasionally find it to be, to particular portions of the scale; they always penetrate every one of the lamellæ, and thus communicate with each parallel layer of lacunæ, through the canaliculi of which the necessary lateral communication can be carried on*.

There is in addition, a third set of still larger, though less numerous canals, which pass completely through the scale, fig. 1 *g*. These are supposed by M. Agassiz to convey the blood through the scale in order to supply the epidermal layer by which it is covered. Existing, as we shall subsequently see, in nearly all the fossil species, they obviously play an important part in the economy of the scale, by keeping up a free communication between its upper and lower surfaces. They are not confined to, or even chiefly found in, the anterior portion of the scale, which, when *in situ*, is embraced by the thick duplicature of the skin, but in that part of it which is free, and which has beyond doubt been covered over with a thin secreting membrane like a periosteum, and which has received some of its supply of blood through these open canals, by means of anastomosing blood-vessels, ascending from the integument below. About the posterior two-thirds of each scale is covered over with a layer of ganoin. In some parts this is so thin as to be scarcely visible, figs. 1 *h* and 2 *f*, whilst in others it is developed into irregular tubercles, fig. 2 *g*. From the latter representation, we see the way in which these tubercles of ganoin are formed. They are, in fact, prolongations of the upturned edges of the bony lamellæ, running towards the centre of the scale, but only covering small portions of the surface, instead of uniformly extending over the whole, as we shall afterwards find to be the case in *Lepidotus* and other fossil forms. We see from this, that each lamella of the ganoin was formed contemporaneously with that of the bone from which it springs; each lamina, shown in the drawing, consists of a number of more minute lamellæ, as has been already observed in reference to the osseous portions. With the exception of the tubes, of which the orifices have been already alluded to as perforating its laminæ, I have not been able to detect any other microscopic structure than these lamellæ in the ganoin.

I subjected some of these scales to the decalcifying action of dilute hydrochloric acid, and obtained a dense flexible tissue, preserving all the original contour of the scale. In this were still exhibited the three sets of canals or tubes, and the lacunæ with their canaliculi. The traces of the lepidine tubes were to be seen so crowded together as apparently to compose almost the entire tissue of the scale. Sections taken at right angles to these tubes exhibited very similar appearances to what are seen in a corresponding section of the decalcified tooth of a Cachalot, or any other

* These tubes appear to correspond with those to which Prof. Owen has applied the term "plasmatic." But as he includes under this title all those commonly known as canaliculi, radiating from the lacunæ, which are obviously distinct in their nature, I think it will serve the purpose of rendering our descriptions more clear, if we employ a new term to distinguish those which I have designated "lepidine" tubes. See the Lectures on the Comparative Anatomy and Physiology of the Vertebrate Animals, by Prof. Owen, part 1, p. 28. This eminent anatomist appears to have noticed them in the scale of the Sturgeon.

analogous form of dentine. But what I more especially sought for I obtained, in the comparative ease with which vertical sections could be torn into fragments along the lines of the original lamellæ, in the same way that Dr. SHARPEY has demonstrated in the case of human bone*. This result left no doubt on my mind as to the applicability of the views of LEEUWENHOEK and AGASSIZ to the scales of *Lepidosteus osseus*, being thoroughly convinced that their formation was accomplished by the successive organization of separate lamellæ, though this organization was not confined, as imagined by LEEUWENHOEK, to the inferior surface.

I may observe, that on decalcification, the lacunæ and tubuli did not disappear, as is stated by M. AGASSIZ, though they became somewhat less distinct, as they do in human bone under similar circumstances. This latter example has been already explained by Dr. SHARPEY†; and his explanation is probably applicable to these bony scales: consequently the circumstance of the lacunæ and tubuli becoming somewhat less conspicuous after decalcification, does not militate against the idea of their being cavities.

Did any doubt exist however on this point, the long streams of air-bubbles which issue out of them on mounting a section in Canada balsam would settle the question.

Employing this scale of *Lepidosteus* as a valuable, and I believe the only recent, type of its class, we will proceed to examine those of some of the numerous fossil genera which have been constructed upon the same general plan. These are especially the widely-diffused genera of *Lepidotus*, *Seminotus*, *Dapidius*, *Tetragonolepis*, *Pholidotus* and *Ptycholepis*.

Lepidotus.—The scales of two species of this genus have already been examined by M. AGASSIZ with reference to their microscopic structure, *L. unguiculatus* and *L. gigas*. Of the former, he merely notices the superimposed arrangement of the lamellæ‡. Of the latter he says, "Lorsque l'émail est enlevé, on aperçoit à la surface de la partie osseuse les bords des lames d'accroissement dont se composent les écailles, et de distance en distance des lignes plus marquées, indiquant des interruptions dans l'accroissement; elles sont causées par l'usure des bords des dernières lames qui ont précédé un nouveau développement. Je me suis assuré par l'examen des poissons vivans que ces interruptions étaient périodiques et annuelles§."

The most beautiful scale belonging to the genus which has come under my notice, is that of the *L. semiserratus*, from the Whitby lias, two representations of which are given in figs. 3 and 4. The general form of the scale is rhomboidal, having one of its free margins furnished with large teeth, two other sides of the rhomboid having been imbedded in the soft integument, and overlaid by the margins of the adjoining scales.

On making a vertical section of the scale (fig. 3) in the direction of the lateral line, we find it to consist of well-marked parallel laminæ, varying from $\frac{1}{30}$th to $\frac{1}{400}$th of an inch in thickness, which, as in *Lepidosteus*, though in a less degree, are turned

* Dr. QUAIN'S Anatomy, 5th edition, by Dr. SHARPEY and Mr. QUAIN, p. cxlii. † *Ut supra*.

‡ Poissons Fossiles, vol. ii. p. 253. § Ibid. vol. ii. part 1, p. 237.

upwards at an acute angle round the margin of the scale—especially on the two sides that are fixed in the soft integument—from one of which the section represented in the sketch (fig. 3) was made. These laminæ are composed of a multitude of still more minute lamellæ. They are perforated by a number of narrow parallel tubes $\frac{1}{2600}$th of an inch in diameter, the greater proportion of which ascend direct from the inferior surface to the region immediately under the ganoin, fig. 3 *a*; but in the anterior margin of the scale these tubes abandon the vertical and assume the horizontal one, or even descend obliquely (fig. 3 *b*), but always run at right angles to the plane of the laminæ through which they pass. In the latter case, instead of terminating, like the vertical ones, immediately under the ganoin, they do so at the angles which the various lamellæ make, when assuming the upward direction; many of them even appearing to take their rise from the under surface of the ganoin, as at fig. 3 *c*; but in the latter case the tube was originally in the position of fig. 3 *d*, its orifice having been subsequently covered over by the formation of newer lamellæ of bone and ganoin.

At the two free margins of the scale which overlap the concealed borders of those behind them, the tubes ascend from the lower surface, as shown at fig. 5 *b* (which represents a similarly constructed scale of *Seminotus rhombifer*). On reaching the ganoin these tubes become branched; their ramifications spreading out in a very thin layer, which covers the outer surface of each of the ridge-like projections which form the upper boundary of the vertical osseous laminæ. This layer consists of a substance alike distinct from the ganoin above and the true bony tissue below, and to which I propose to give the name of Kosmine (from κόσμειν, *to adorn*). It is much more dense in its structure than the true bone containing no lacunæ (though these, as the case in the example before us, are often seen through it), but is always furnished with some arrangement or other of minute branching tubuli. This kosmine, which has hitherto been confounded with the ganoin, under the common name of "enamel," occurs so frequently as to constitute an important feature in many ganoid and other scales, and consequently requires to be distinguished from the transparent and almost structureless tissue to which I have limited the application of the term *ganoin* throughout this memoir.

The exquisitely beautiful appearance produced by this distribution of the tubes in the scale under consideration, is shown in fig. 4 *a*, which represents the upper surface of that portion of the scale as seen through the transparent ganoin. The sharp tooth-like ridges presented in the vertical section, fig. 3 *c*, are here more highly magnified, and form parallel spaces, fig. 4 *a*, before reaching which, the tubes usually divide into two or three branches, which afterwards give off beautiful arborescent ramifications, reminding us of leafless trees in winter. These communicate freely with one another, by means of anastomosing loops, in the arches of which some of the small lateral twigs dilate into crescentic cavities, fig. 4 *b*. The branches of each tube are usually limited, in their distribution, to the one lamina to which it is destined, but some-

times, after thus giving off a group of branches, the main trunks pass on to supply the next lamina which lies on the inner side.

This distribution of tubes on the extremity of each lamina, shows that the more strongly-marked lines of division which separate them, in contradistinction to those merely dividing the lamellæ, are not due to "l'usure des bords des dernières lames qui ont précédé un nouveau développement," but to some internal physiological cause, which, whatever it has been, may have operated annually, as is supposed by M. Agassiz.

In the central and earliest formed lamellæ, these tubes terminate as at fig. 3 *b*, *c* and *d*, by subdividing into two or three small branches, but do not exhibit any extensive ramifications. The same is also the case with the tubes of the two opposite margins which terminate in the interior of the scale.

We also find in this scale a development of lepidine tubes; they are not diffused throughout its whole extent, as in *Lepidosteus*, but appear to be chiefly confined to the margins; and even there, only exist in those portions of the lamellæ which assume the oblique and vertical directions. These latter are copiously perforated by them, fig. 3 *f*, but the horizontal portions exhibit few, if any, traces of their existence.

Between each of the contiguous lamellæ is distributed a layer of lacunæ which exhibit the same features as those of the *Lepidosteus* already described. In the parallel spaces of fig. 4 we only see the edges of the lacunæ and their canaliculi following the plane of the ascending lamellæ.

On the upper surface of the scale is found a thick deposit of ganoin, the formation of which, the section represented in fig. 3 enables us to comprehend. At *g*, like the subjacent part of the scale, it consists of parallel laminæ, each of which, under a high magnifier, is seen to be again separated into still more minute lamellæ. At *h*, we find that each of the laminæ is merely a prolongation of a corresponding one in the osseous portion, only having the character of ganoin instead of bone, and separated from it by the thin film of kosmine already described. To some extent we found the same condition to exist in *Lepidosteus*, only the kosmine was wanting, and what was there seen to be a partial and unequal distribution, producing irregular superficial tubercles, here extends uniformly over the whole scale, showing that, in *Lepidotus* at least, each new growth has completely surrounded all that had been previously formed, enclosing it as a nut does its kernel; only the upper portion was ganoin, whilst the lower one was true bone.

We also find in the large opercular bone of the same *Lepidotus* a still further resemblance to the scales of *Lepidosteus*, in the existence of similar large canals communicating between its upper and lower surfaces. I have observed sections of these to exhibit concentric laminæ surrounding the canals, showing that the membrane which lined them was also a secreting tissue, depositing calcareous matter, and was doubtless a prolongation of the periosteum already spoken of. These concentric lamellæ do not

all exhibit complete circles, those forming the canal alone doing so; on one side of, and external to the latter, we often observe a number of half-circles, as if it had for a long time been merely a groove at the margin of the scale. In other respects, the bony lamellæ of the operculum exhibit the same appearances as those of the true scales, and prove that it has been formed by a similar deposition of laminæ. This close resemblance between the minute structure of the scales and opercular bones of *Lepidotus* seems to support the view once entertained by Prof. Owen, but since abandoned by him, that the opercular bone is merely a modified scale, and consequently belongs not to the endo- but to the exo-skeleton.

Lepidotus Mantelli and *L. fimbriatus* have scales of a similar structure to those of *L. semiserratus*, only the latter appears to want the beautiful ramifications of the kosmine. The central tubes which ascend from below all terminate in short branches like those seen in the centre of the last-described scale. The ganoin of *L. Mantelli* is filled with minute brown granular points; but whether these are parts of its original structure, or whether it is merely an effect of fossilization, I am undecided. I suspect the former to be the case. Similar, but still more minute, granules exist in great abundance in the ganoin of *L. fimbriatus*.

Seminotus.—Fig. 9 represents a vertical section of *Seminotus rhombifer*, taken parallel to the mesial line of the fish. It exhibits an excellent illustration of the general contour of this class of fossil scales: *a* is the anterior extremity, which is imbedded in the soft skin, its oblique margin being overlapped by the scale in front of it: *b* is the opposite edge, adapted for resting on the anterior bevelled portion of the adjoining scale. We have the same arrangement of laminæ, lamellæ, lacunæ, canals and lepidine tubes as in *Lepidotus*, only we want the arborescent ramifications of the kosmine tubes. The ganoin exhibits the laminated structure found in the other scales.

Pholidotus.—In *Pholidotus Leachii* we have a close resemblance to the scale of *Seminotus rhombifer*, only the edges of the upturned laminæ, as seen in a vertical section, exhibit less of a tooth-like arrangement; and amongst the lower laminæ of each scale is developed a large central lenticular cavity, produced by the divergence of some of the last-formed layers. I have not yet discovered any traces of an opening into this cavity, though there most probably is one. The parallel tubes take their rise from it as from the bases of ordinary scales, ascending towards the ganoin.

Ptycholepis Bollensis.—In the structure of the small thick scale of this curious species, we find a resemblance to that of *Lepidotus semiserratus*. The parallel ascending canals terminate in a similar thin layer of kosmine, which exhibits three or four parallel rows of anastomosing loops, giving off minute branching tubuli. The ganoin, which is unusually thick, exhibits precisely the same laminated structure as that of the *Lepidotus*.

Beryx.—The scales of a new species of this genus, from the Chalk of Sussex, belong to the same group. We find the large canals, like those of the *Lepidosteus*, commu-

nicating between the two surfaces of the scale—the parallel ascending tubes, which, as in *Lepidotus semiserratus*, terminate in a considerable development of kosmine, the elevated ridges of which project into the ganoin. The anastomosing loops of the kosmine are in every way larger and stronger than in any species hitherto described, the numerous branches and twigs which they give off from their elongated arches exhibiting the appearance of *chevaux-de-frise*.

Dapidius.—In *Dapidius orbis*, the lamellæ of the scale are exceedingly distinct and beautifully parallel, but the division of them into laminæ is less obvious. We have the large canals communicating between the two surfaces, causing the puncta on the exterior of the scale, and the parallel tubes as in the *Lepidosteus*. The lepidine tubes are very extensively developed, especially at the anterior margin of the scale. The ganoin is remarkably thin, and in some examples scarcely visible.

In *Dapidius granulosus*, the substance of the scale has the same structure as that of *D. orbis*, but its surface is studded over with scattered raised points, one of which, as seen through the superficial ganoin, is represented in fig. 5. Each one forms an elevated point, the posterior portion of which (*a*) exhibits a defined convex edge. It is covered with a layer of ganoin, which is but slightly developed over the intervening layer of the scale. This is seen in fig. 6 *a*, which represents a vertical section of one of these tubercles, made in the direction of the dotted line, fig. 5 *c c*. Under each of these exists a small cavity, figs. 5 *b* and 6 *b*, which opens externally, by means of three or four small canals, fig. 5 *d*, the orifices of which are placed behind the tubercle. Above this cavity we have a development of kosmine, the tubes of which chiefly arise from the anterior side of the cavity, 6 *e*, 6 *c*. Thus we find that each of these tubercles consists of a local development of kosmine and ganoin upon the upper laminæ of the scale, fig. 6 *d*, these latter being constructed on the ordinary type seen in so many of the lepidoid scales. To this limitation in the distribution of the kosmine and ganoin we shall have to refer again, as it constitutes one of the earliest forms, in which the tendency existing in many fish to the development of dermal teeth-like structures, manifests itself.

Palæoniscus.—This genus, of which I have investigated two species, the *P. comptus* from the magnesian limestone of Durham, and the *P. Beaumonti* from Autun, is allied in many respects to the group already noticed. In the arrangement of the laminæ and lamellæ, the scales of the above species exhibit the general aspect of the Lepidoids already described, but they materially differ in the distribution of their system of internal canals.

On making a vertical section of the scale of *P. comptus*, parallel with the mesial line, we see none of the long parallel tubes traversing the laminæ at right angles, which form so conspicuous a feature in the scales hitherto described. In other respects, the laminæ, fig. 7 *e*, both in their horizontal and upturned portions, as well as the lacunæ and their canaliculi, agree with those of *Lepidotus* and its allies.

On looking through the ganoin, when the lower portion of the scale has been

ground away to render it more transparent, we find a beautiful arrangement of tubes or canals running immediately under and in the plane of the ganoin, forming, by their branches, a development of kosmine. The main channels (7 *a*) are slightly undulated, and send off to each lamina small lateral twigs (7 *b*), which, anastomosing with similar ones from adjoining tubes, form a series of loops, the arborescent terminal ramuli of which supply the parallel lines of the kosmine with nutriment.

The subjacent laminæ may be ground so thin as to exhibit no trace of either lacunæ or any other kind of cavity or perforation whatever, appearing merely as a structureless calcareous layer separating two layers of lacunæ and their parallel planes of canaliculi. There appears to be no way in which these horizontal laminæ could receive their nutriment except through the lepidine tubes. The latter abound at each extremity of the section, where the laminæ leave the horizontal to assume the upward direction: through the branches of these tubes the nutrient fluid might reach each layer of lacunæ, and, by means of their canaliculi, be distributed laterally to every portion of the scale. The lacunæ are somewhat larger than in *Lepidotus semiserratus*. I have found, that, however various may have been the dimensions of the scales under examination, there is but little difference in the size of their lacunæ. The centre of each scale of *P. Comptoni* (7 *c*) merely exhibits a layer of these lacunæ, and corresponding ones, following the plane of the upturned laminæ, are seen edgeways through the kosmine, 7 *d*.

M. Agassiz describes the enamel (*émail*) of *Palæoniscus* as being nearly opake. It is, however, not more so than in any other genus.

The scale of *P. Beaumonti* resembles that of *P. comptus* in its general features, but differs in points of detail. The large tubes or canals supplying the kosmine chiefly enter at the sides of the scale, Plate XLI. fig. 8 *a*. They do not terminate at the central rhomboid in the fine filamentous loops which characterise *P. comptus*, but some of the large tubes traverse this central portion, and communicate with corresponding ones entering from the other sides of the scale, 8 *b*. Along the upturned edge of each of the laminæ, and parallel with it, are large transverse inosculating branches, 8 *d*, which, by connecting the main trunks together, form a network, from which are given off a vast number of minute branching filaments; these are distributed to the thick layer of kosmine. On one side these anastomosing branches are very long, their extent being occasionally equal to the entire diameter of the scale, 8 *e*, owing to the entire absence, in this portion, of the large trunks which enter laterally. The very few which are visible, instead of being parallel with the ganoin, seem somewhat to ascend from below, 8 *f*. The same is the case with some of the main trunks at the angles of the scale, 8 *c*.

Its anterior and posterior margins are freely supplied with lepidine tubes.

No pencil can adequately depict the beauty of the filamentous branches of the anastomosing canals in the kosmine of this interesting scale. Though differing in

some of its details from that of *P. comptus*, the two evidently belong to one common type, which is distinct from any previously described. So far as the nutrition of the kosmine is concerned, the horizontal canals evidently fulfill the functions of the parallel vertical ones amongst the *Lepidoti*; they do not appear to contribute any branches to the osseous lamellæ, which, as in the case of the *P. comptus*, must be nourished through the lepidine tubes.

Gyrodus.—The scale of a species of *Gyrodus* from Kellheim exhibited the appearance represented in fig. 9*. It is a modified form of the type found in the *Lepidosteus*, presenting similar laminæ, lamellæ, parallel tubes, and lepidine. The anterior portion of the scale, 9* *a*, which is very much thickened, exhibits well-marked concentric lamellæ, which become curiously inflected towards the centre of the scale. Owing to these inflections, the posterior portion, which rests on the thickened extremity of the one behind it, suddenly becomes very thin, fig. 9* *b*, but still preserving its laminated structure, and divisible into two parts; a lower one, in which the large tubes ascend from below, fig. 9* *c*, and an upper one, in which they enter from above, fig. 9* *d*. These tubes are much less numerous and less regularly arranged than in the majority of the preceding scales; those especially which come from above exhibiting less parallelism. The anterior extremity of the section, which when *in situ* has been deeply imbedded in the soft integument, is abundantly supplied with lepidine tubes, fig. 9* *e*; those from the upper surface inclining downwards, and those from the lower margin running upwards in the direction of the centre of the scale.

The sudden inflection of the laminæ produces the appearance of the thick transverse rib, extending over the breadth, which is the longer axis, of the scale.

Aspidorhynchus.—In the large scale of *Aspidorhynchus acutirostris*, from the lithographic stone of Solenhofen, we find a somewhat analogous structure to the last, only without the contracted inflections of the laminæ. The bulk of the scale consists of an arrangement of lamellæ, perforated by beautifully defined and regular parallel tubes, the interlamellar spaces being occupied by layers of magnificently developed lacunæ with their branching canaliculi. These last are more beautiful than in any species of fish which I have examined. The upper surface of the scale exhibits a series of large and nearly parallel ridges and furrows: a vertical section (fig. 10 *a*) shows these ridges to be formed by an undulatory arrangement of the upturned lamellæ, which here take the place occupied by the ganoin amongst the *Lepidoti*. These undulating lamellæ are perforated from above by a series of tubes, fig. 10 *b*, which, like those coming from below, fig. 10 *c*, terminate in a kind of neutral line between the upper and lower portions, which is about one-third of the thickness of the scale below its upper surface.

If there is any ganoin upon the scale, it is so thin as to be invisible. Its place is occupied by these wavy lamellæ; and not only do the latter occupy its position, but they produce those superficial irregularities, which in *Lepidosteus* are due to the distribution of the ganoin: they have obviously been produced by the superior por-

tion of the periosteal membrane corresponding to that which forms the ganoin in the other scales.

Acipenser.—Sections of the scale of the common Sturgeon present a structure somewhat similar to that existing in the *Aspidorhynchus*, only the numerous ascending parallel tubes are wholly wanting, and the process of involution of the upper portions of the lamellæ has been carried to a much greater extent, leading to the production of true Haversian canals.

When one of the large lozenge-shaped scales is examined, its upper surface is found to be rough and thorny. This is owing to the existence of what at first sight would appear to be a deposition of something resembling ganoin upon the true bony tissue: this hard substance, which covers the free portion of each scale, has a tendency to be arranged in the form of radiating ridges, extending from the centre to near the circumference of the scale, excepting on the anterior portion, which, having supported the opposite margin of the preceding scale, is quite smooth, as is also the inferior surface. In the central portion of the upper surface the radii are less regular than towards the posterior edge of the scale, being more cribriform in their aspect, from the existence of numerous irregular pits and deep depressions which exist in it. A smooth elevated ridge crosses the centre parallel with the lateral line; this covers over a very large canal, the superficial opening of which is in the smooth anterior portion of the scale, which has been covered over by the upper fold of the integument: its opposite extremity is at the under surface of the scale, near its posterior border. The canal has obviously transmitted blood-vessels, and probably nervous twigs also, keeping up a free communication between the two portions of the integument. Several smaller but analogous canals communicate between the upper and lower surfaces, each of them verging towards the centre as it ascends.

The lower surface is very smooth and translucent, exhibiting a series of concentric lines, like those in the interior of a bivalve shell, and which at first glance might lead to the idea that the enlargement of the scale had been accomplished, as in the shell, principally by the addition of new matter to its edges. Such, however, is not the case. These concentric lines are in reality only the points at which the successive laminæ constituting the inferior portion of the scale turn upwards and inwards at a very acute angle, as seen in the section, fig. 11 *a*: these lines of course represent what were from time to time the external boundaries of the scale, which were enclosed by successive new growths.

As we have seen to be the case in *Aspidorhynchus*, soon after leaving the horizontal condition, the upturned laminæ present a strong tendency to undulate, but even to a much greater degree. Near the margins of the scale, these undulations only produce alternating grooves and ridges on the surface. This appears to be the portion figured by M. Agassiz*; whose representation, however, gives a very imperfect idea of its true structure. But as the section approaches the centre of the scale, we find that

* Poissons Fossiles, vol. ii. Tab. H. fig. 22.

by the deposition of new layers, these grooves are covered over and converted into true Haversian canals. As we should expect to be the result of this mode of growth, none of the laminæ forming these canals exhibit complete circles; the involutions of the lower layers are met by corresponding ones in the upper laminæ; and by the juxtaposition of their respective salient points, the canal is rendered complete. Thus in fig. 11, the depressions *b* are quite ready to be covered over in the same way as the completed canals *c*, and doubtless, in time, the addition of new laminæ would have so closed them in. The whole of the scale is abundantly supplied with lacunæ and their stellate canaliculi, though in the inferior horizontal portions of the lamellæ these are not so beautifully distinct as in those surrounding the Haversian canals. The latter portions are also freely supplied with minute branching lepidine tubes, which descend from above, and, with the exception of the large canals already described, appear to be the only tubes the scale contains*. This beautiful illustration of the way in which Haversian canals may be formed is one of great value to the physiologist; because, from the size and distinctness of the laminæ, and the ease with which their direction can be traced, they leave no possible room for doubt on the subject. We thus derive, from this comparatively remote source, strong corroborative evidence of the accuracy of Professor Sharpey's views respecting the origin and mode of formation of the analogous structures in human bones.

Platysomus.—Constructed on the same principle as those already noticed, but exhibiting a very curious modification of it, is the scale of *Platysomus parvulus*, from the upper coal-measures of Leeds and Manchester.

The exposed part of the upper surface of this scale is covered with deep grooves and intervening ridges, running nearly parallel with its long axis, which, as in *Gyrodus*, really represents its breadth, and is at right angles to the direction of the lateral line of the fish.

On making a section of the scale in the opposite direction to that taken by these ridges, we find it to consist of two portions, an upper and a lower one. The latter, figs. 12 *a* and 13 *a*, though apparently of a dense homogeneous structure, exhibits, on a careful examination, clear evidence that it consists of a series of minute lamellæ, though these do not appear to be aggregated into any more conspicuous laminæ. In the upper portion, we find that each elevated ridge consists of a series of concentric arches, fig. 12 *b*, having intervening crescentic spaces, 12 *c*, and exhibiting traces of the existence of canals, connecting one set of arches with another. On making a section in the opposite direction, along the line of one of these elevated ridges, fig. 13, this structure is more fully explained; and each individual ridge shown to be formed by a series of arching plates, 13 *b*, which arise from the compact portion of the scale, 13 *a*, and after successively overlapping each other, losing themselves at the upper surface of the scale. In fig. 14, which represents a horizontal section, taken in the

* These were noticed by Prof. Owen, and recognized as belonging to his "plasmatic series." See Lectures on the Vertebrate Animals, part 1, p. 31.

plane of the line 12 *e*, *f*, the same letters are employed to mark the corresponding portions of the two sections: thus, whilst the portion 14 *e* dips rather deeply into the lower part of the scale, the oppposite one, 14 *f*, cuts across the bases of the arches 14 *b* shortly after taking their rise from the body of the scale. We see that they do not spring up at right angles to the axis of the ridge, but obliquely; the section of this portion of each intervening cavity, 14 *c*, being somewhat pyriform. Each lamina is about $\frac{1}{1600}$th of an inch in thickness. Between these and the body of the scale is a series of anastomosing canals, 14 *d*, which connect the isolated cavities together, opening into them by small oval orifices, 14 *h*. Traces of the corresponding canals are seen in 12 *d* and 13 *d*, whilst their orifices are likewise shown in 12 *h* and 13 *h*.

In the lower part of this section, 14 *e*, we find numerous laminæ cut through somewhat obliquely, 14 *g*. These are also seen in the two vertical sections.

Singular as is the construction of this scale, a very careful investigation of it has satisfied me that it is formed on the type of those previously described. The pointed extremity of the section, fig. 13, represents the anterior margin of the scale, which has been covered with the fold of soft integument and by the free edge of the antecedent scale; the curious arched plates, 13 *b*, are in reality formed by the upturned portions of the lamellæ, and probably correspond with the laminæ of the other scales; each of them, whilst enclosing those previously existing, has not been deposited in immediate contact with it, but intervening spaces have been left; whilst between each of these cavities there exist connecting channels admitting of a free vascular intercommunication. The cavities and the canals together appear to be the representatives of the true Haversian canals; the large cavities bearing the same relation to the connecting passages, probably, that the large cancelli of Mammalian bones do to the Haversian canals which open into them. Each of the arched plates contains numerous lacunæ, with peculiarly long trailing canaliculi, especially at the surface of the scale. No appreciable layer of ganoin covers these arches.

The modifications of the Lepidostean type of scale found in *Aspidorhynchus* and *Acipenser*, conduct us to some of the most complicated and beautiful structures that I have yet seen amongst the ganoid fish, occurring in the genera *Megalichthys*, *Diplopterus*, and *Holoptychius*; but notwithstanding all their complications, it is not difficult to trace the same principle of growth which we have thus far seen to apply in every case.

Megalichthys.—The matured scales of this genus exhibit on their exposed surfaces a layer of bright shining ganoin, which is densely covered with minute puncta. These were noticed by M. Agassiz, who says, respecting them, "Ce sont des petits points creux, extrêmement rapprochés, et dont les intervalles en relief forment un réseau de mailles*." On making a vertical section of a scale of *Megalichthys Hibbertii* from the upper coal-measures of Lancashire, fig. 15, I found that each of these puncta constituted the orifice of a vertical trumpet-shaped cavity, 15 *a*, very narrow superiorly, but expanding and becoming triangular or quadrangular inferiorly. This is well shown

* Poissons Fossiles, vol. ii. part. 2, p. 154.

in Plate XLII. fig. 16, which represents a horizontal section of the upper surface of the same scale, as seen when looking downward through the transparent ganoin. The inferior portion has been more freely ground away at the light-coloured extremity *h*, than at the opposite one, where the section retains some of the deeper osseous layers; consequently these vertical cavities are here cut across at their narrowest part and exhibit a circular contour, 16 *a*, but in the middle portion, we find that the section has passed through these cavities lower down, where they assume a triangular or quadrangular form, 16 *b*. In their upper and middle part, we not unfrequently see them to be surrounded by concentric rings, reminding us of the rudimentary Haversian canals in the opercular bone of *Lepidotus semiserratus*. After descending a little distance, these cavities give off three, four, or five narrow horizontal tubes, which communicate with contiguous cavities, 15 *c*; thus combining to form a horizontal network which lies a little below the superficial ganoin. Neither these cavities nor the tubes into which they thus subdivide give off any minute branches. They are obviously but the channels of communication which lead to more important tissues. After giving off the tubes, the cavity becomes suddenly constricted, and, descending a little further, connects itself with a second and more irregular network of larger canals, 15 *d* and 16 *d*, constituting the uppermost of the Haversian canals. The meshes of the network of tubes 15 *c*, 16 *c*, constitute a series of cup-shaped areolar spaces, 15 *e* and 16 *e**; into each of which the second layer of canals sends up an ascending branch, or cul-de-sac, like the stump of a pollard willow, 15 *f*, 16 *f*. This gives off a multitude of ramifying tubuli, the main branches of which ascend, and distribute their terminal ramifications immediately under the ganoin. Their distribution is very well seen in the horizontal section 16, in the thicker extremity of which the branches are still connected with the cul-de-sac from which they spring, 16 *f*, whilst at the opposite end we have only the branches or their terminal twigs remaining, 16 *h*, the cul-de-sac being wholly ground away. The inferior portion of each areola is supplied with exceedingly minute recurved tubuli, which spring from the same point as the larger ascending branches.

In each of these areolar systems, four or five of the branches, instead of subdividing until they become wholly lost, retain their original calibre, and connect themselves laterally with corresponding branches from adjoining areolæ, forming a third network (16 *g*, 17 *b*) which is still nearer the ganoin than the other two, and which gives off numerous minute horizontal and ascending twigs.

After thus giving rise to these three well-marked systems of reticulations, distributed in the plane of the surface of the scale, the trumpet-shaped cavities continue their downward course, when they become lost in an irregular network of Haversian canals, 15 *b*, which generally terminate inferiorly, in others of a much larger size,

* In the large scales of *M. Hibbertii*, each of these areolæ have an average diameter of $\frac{1}{110}$th of an inch. In the smaller species from Leeds, fig. 17, they average about $\frac{1}{180}$th of an inch.

15 *g*; and which usually exhibit a tendency to run parallel with the long axis of the scale.

In fig. 15 these are cut transversely, but in fig. 17, which represents a vertical section of a smaller species of *Megalichthys* from the coal-measures near Leeds, the large canal is divided longitudinally, 17 *g*. In this latter species, the ramifications of the Haversian canals are much less extensively developed than in *M. Hibbertii*. The same is the case with an analogous scale from the old red sandstone of Cromarty.

With the exception of the thin superficial layer of ganoin, 15 *h*, all that portion of the scale which lies above the plane of the network of narrow tubes, 15 *c*, consists of a beautiful and largely developed form of kosmine; the remaining channels are Haversian canals, penetrating true osseous tissues. The two structures merge in each other through the ascending cul-de-sacs.

Below this system of Haversian canals, we find a large development of exceedingly thin parallel laminæ, the majority of which extend completely across the scale, fig. 15 *i* and 18 *a*, each having an average thickness of about $\frac{1}{1500}$th of an inch. Their number and regular parallelism are alike the greatest towards the central and anterior portions of the scale. As we approach the posterior margin, each one becomes thicker, less uniformly parallel, and more disposed to curve upwards, mingling with those forming, by their involutions, the Haversian canals.

Inferior to these parallel laminæ, which divide the scale horizontally into two portions, we find a second distribution of Haversian canals, fig. 15 *k* and 18 *b*. They are especially developed along the centre and across the anterior extremity of the scale, where they form a projecting ridge. I have not found any example in which these canals penetrate the parallel laminæ towards the centre of the structure to any considerable extent; but as we approach the anterior margin, where the laminæ lose much of their parallelism, a free communication is established between the upper and lower portion by means of large anastomosing canals. Along the inferior surface the outline is exceeding irregular, in consequence of the existence of the numerous open orifices of these canals, and where, as at fig. 15 *l*, incipient canals are in process of formation, like those already described in the scale of the Sturgeon. On the upper surface of the anterior portion of each scale, also, where from the juxtaposition of the upper fold of the soft integument no ganoin was needed, and consequently it did not exist, we find precisely the same structure, which is one reminding us most strongly of the aspect presented by the section of a human fœtal bone. Through these open canals, blood-vessels have had free access to every part of the scale. Fig. 15 is taken from near the lateral portion of a scale, where the extension of the inferior system of Haversian canals is limited, but fig. 18 is from a section which cuts across the central ridge already described, and where the degree of their development is well shown. In this specimen the ganoin has been accidentally removed.

With the exception of the ganoin and kosmine, all the various modifications of laminæ in this scale abound in lacunæ. The bony matter surrounding the Haversian canals is deposited in concentric lamellæ, between which are numerous lacunæ with their stellate canaliculi of various forms, usually of the common ichthyal type; but sometimes, especially in the lamellæ nearest to the canals, showing a disposition to become elongated in the direction parallel to the axis of the latter. In the horizontal laminæ, already described, fig. 15 *i*, we find a very curious form of lacuna. They are very much elongated, being about $\frac{1}{300}$th of an inch in length, and sometimes almost linear, giving off numerous rectangular canaliculi. Not unfrequently these spring from the lacuna diagonally; those on different sides verging to the opposite extremities of the lacuna, as is seen in fig. 19 *b*, which sketch represents the appearance of these lacunæ as seen under a magnifier of 300 diameters linear. Those of each layer exhibit a considerable tendency to parallelism of arrangement, but owing to the extreme thinness of the laminæ, the lacunæ belonging to two or three layers may be seen at once, even under a magnifying power of 300, as shown in fig. 19: and it is a curious fact, that those constituting one layer exhibit a very considerable tendency to run in the direction of the canaliculi of an adjoining layer. In fig. 19, *a*, *b* and *c* represent individual lacunæ belonging to three of these parallel series. In addition to the above, each lacuna gives off small vertical canaliculi, which penetrate the lamellæ, and thus connect the different layers together, fig. 15 *i*. These structures become highly interesting when viewed in connection with Mr. Quekett's instructive attempts to identify the bones of the four classes of the Vertebrata by means of the variations of their microscopic structure*. In that memoir Mr. Quekett considers that this elongated form of lacuna is characteristic of the Reptilia; and there is certainly a very striking resemblance between his representation of those of the Pterodactyle†, the accuracy of which, my own specimens of the latter confirm, and my fig. 19. We thus find that some of the elementary tissues of this fish, which on its first discovery was so readily mistaken for a reptile, exhibit a most striking resemblance to the reptilian type: I shall have to show, by and by, that the same form of lacuna exists in the genera *Diplopterus* and *Holoptychius*; consequently the fusiform lacuna can no longer be regarded as typical of the Reptilia, as was imagined by Mr. Quekett, though it is unquestionably the form most commonly found in that class of Vertebrata, as the quadrate one is chiefly characteristic of fish: great caution however requires to be exhibited ere we decide a disputed question on this evidence *alone*. I find but little difference between the majority of the lacunæ of the small *Platysomus parvulus*, already described, the scales of which are about the $\frac{1}{18}$th of an inch in length, and those from the gigantic femur of an Iguanodon, in the possession of Dr. Mantell, which, when perfect, he informs me has not been less than 27 inches in circumference at the shaft. A legitimate inference from these

* Transactions of the Microscopical Society of London, vol. ii. part 2. p. 46.

† Tab. 8. fig. 2, *ut supra*.

facts is, that Mr. QUEKETT's objection to the arrangement of the Lepidosiren amongst fishes, as proposed by Professor OWEN, derived from the form of its lacunæ, is not a valid one.

On viewing the variety and complication in the arrangement of the elementary tissues combining to form the scale of *Megalichthys*, it is difficult to resist the conclusion that it must have been constructed on a very different plan to that followed in the genera previously described. I am satisfied however that such has not been the case to any material extent. We have seen that the results arising from the successive organization of lamellæ have gradually increased in complexity as we ascended from *Lepidotus* and *Seminotus* to *Gyrodus*, *Platysomus*, *Aspidorhynchus* and *Acipenser*. This complexity appears to have reached its climax in *Megalichthys*, at least so far as refers to the fish that I have had an opportunity of examining. At the same time there are some points of detail which differ from those which I have observed in the genera already noticed, and consequently I would express myself with legitimate caution on the point.

I believe, however, that some of the parallel laminæ, fig. 15 *i* and 18 *a*, have been formed the first: whilst additional layers were being organized, inferiorly, by intramembranous ossification through the agency of the lower portion of the secreting sac, these laminæ being parallel to their predecessors, the corresponding and coeval portions, being secreted by the upper wall of the sac, were much undulated, their various inflexions laying the foundation of the Haversian canals. After this process has continued for some time, and a considerable amount of thickness been given to the scale, the new lamellæ added to its inferior surface, instead of retaining their parallelism with those already formed, have begun to assume an undulatory arrangement, in the same way that *all* the superior ones, corresponding to the upturned lamellæ of the Sturgeon, had done from the commencement. This inflexion of the newly-added lamellæ did not take place to an equal extent over the entire inferior surface of the scale, but was chiefly confined to the centre and to one extremity; the remaining portions, and especially that occupying the anterior margin, retaining their tendency to horizontal parallelism.

The osseous framework of the scale being thus completed, new processes have come into operation. Prolongations from the periosteal membrane have lined the Haversian canals, and these have deposited new and internal lamellæ—at once thickening their walls and diminishing their diameter—a process, of which we have hitherto met with no trace in the scales of any of the fish described, excepting in the opercular bone of *Lepidotus*.

At some period *prior to* this partial filling up of the Haversian canals, a deposition of kosmine has taken place on the surface of the scale, but of which, also, in the first instance, only the framework has been formed. The careful preparation and examination of numerous sections has enabled me, I trust satisfactorily, to remove much of the obscurity that has hitherto rested upon this portion of the subject.

Each areola has, in the first instance, temporarily presented a similar appearance as is permanently exhibited by some species of *Diplopterus* and *Holoptychius*. The most superficial portion has been separated from the textures below by a large horizontal cavity, into which the numerous extensions of the Haversian canals destined to form the cul-de-sacs have opened. This superficial chamber has only been traversed by the hollow pillars of kosmine surrounding the descending trumpet-shaped cavities. The framework of the kosmine has been penetrated by a multitude of exceedingly minute tubuli, opening into the diffused chamber. As new internal organizations of bone have filled up the Haversian canals, prolongations from the osseous lamellæ have also contributed to fill up this open space, by thickening the walls of the hollow pillars and their narrow tubular canals, as well as the uppermost layer which supports the ganoin. The increase of these depositions has led, after a time, to the closing up of the channels communicating between contiguous areolæ, a small aperture only being left permanently open, constituting the network of narrow tubes, fig. 16 *g*. The concentric walls of the hollow pillars, fig. 16 *a*, thus becoming confluent, the central cavity of each areola has been isolated; and further organizations have narrowed its dimensions, until nothing remained of each originally large space but the permanent cul-de-sac, into which the minute tubes, gradually uniting to form the larger branches penetrating each succeeding lamella, have ultimately opened.

This process has gone on with the increasing age of the fish, until in some instances the cul-de-sac is nearly obliterated, leaving only a narrow vertical tube or stem, supporting the arborescent arrangement of tubuli. In some of my sections these lamellæ are beautifully distinct, the innermost ones following the outline of the cul-de-sac, and the outer ones that of the trumpet-shaped cavities around which they were deposited. This arrangement is represented in the areolæ of fig. 15. We should infer that in young fish the cul-de-sacs of the kosmine and the Haversian canals of the bone would be very large in proportion to the solid tissues of the scale, and I can even believe it possible that scales of a very young individual might easily be mistaken for those of a *Diplopterus*. I possess sections of the latter which exhibit precisely this condition. The Haversian canals appear as very large cancellated cavities, and the structure of the kosmine also resembles the early state of *Megalichthys* as just described.

There appears to be a period in the history of the scale when its kosmine ceases materially to increase in its superficial diameter. This extension seems to have reached its limit when the deep grooves which mark the boundary of the kosmine on two sides of the scale are formed. Further additions of bony substance continue to be made inferiorly, as well as to the upper surface of the two margins, which, being imbedded in the soft integument, need neither ganoin nor kosmine; these being the portions where the development of the two latter is arrested by the groove. Whether or not any additions continue to be made to the other two margins which overlap the contiguous scales behind and beneath, I have not been able to satisfy myself.

One question arises to which I am unable to give a decisive answer. May there not have been in this scale of *Megalichthys*, a central nucleus of cartilage in the midst of the Haversian canals, in which the first deposition of calcareous matter may have taken place, and upon which the horizontal lamellæ have been subsequently added by the ordinary process of intramembranous ossification? This is just possible, though we have no evidence of its truth; whilst the scale of a *Holoptychius*, shortly to be described, and presenting a closely allied structure, is opposed to the supposition, and supports the idea, that the scale of *Megalichthys*, complicated as it is, has been wholly formed by the successive organization and inflexion of layers of membrane in which the granules of calcareous matter have been subsequently diffused.

Diplopterus.—M. Agassiz has already examined some species from the old red sandstone. He remarks, "Les écailles présentent une fine granulation provenant d'une quantité de petits trous qui s'ouvrent de passage pour les nombreux petits vaisseaux sanguins qui traversaient l'écaille pour se rendre dans l'épiderme. Examinées au microscope, les écailles présentent une épaisse couche d'émail, au dessous de laquelle se trouve un tissu osseux montrant des réseaux fort élégants, qui ne diffèrent de ceux de Polyptère que par leur développement considérable. Les trous et les canaux médullaires l'emportent de beaucoup sur les piliers intermédiaires*."

Fig. 20 represents a horizontal section of a very thin scale belonging to an undescribed species from the coal-field near Leeds. The original specimen was about half an inch in length, and, as in *Megalichthys*, was covered with shining ganoin, which was perforated by innumerable minute apertures, the orifices of canals. The section was made at a slightly inclined angle to the plane of the scale, so that whilst the extremity *a* cuts obliquely through the superficial ganoin and its subjacent kosmine, the opposite end *b*, especially to the right-hand of the figure, dips more deeply into the bony tissue of the scale. Though I have not been able to procure a second example of this scale, in order to make a vertical section, there is no difficulty in reading off its beautiful structure, and comparing it with the vertical sections of *Megalichthys* and *Holoptychius*. It corresponds exactly with what has already been described as the immature condition of the former, and closely resembles that presented by one species of the latter.

c is the superficial layer of the kosmine supporting an exceedingly thin film of ganoin; the dark portion *d* is the horizontal cavity, traversed by the hollow pillars of kosmine, *e*, which surround the trumpet-shaped descending cavities: these commence by small apertures in the superficial layer, *f*; at *e* they gradually enlarge, becoming angular at *g*, and at *h* giving off the minute connecting tubes *i*, which correspond with those of the *Megalichthys*, fig. 15 *c*. Below this the descending cavities become lost in the ramifications of the Haversian canals *l*, as at *k*. The small tubes *i* divide the kosmine into areolar spaces, and into the centre of each there arises an offshoot from the Haversian canals, *m*, opening superiorly into the horizontal cavity *d*,

* Poissons de Vieux Grès Rouge, p. 54.

which separates the upper layer of the kosmine from the tissues below. As we have already seen to be the case with *Megalichthys*, neither the descending cavities *e*, *g*, nor the small tubes *i* into which they subdivide, give off any minute tubuli, but their walls are wholly supplied either from the superficial space *d*, or from the cavity in the centre of each areola, *m*. The latter especially give off branching kosmine tubuli of considerable size and great beauty. In the former the tubuli are very small, with the exception of those which ascend to the superficial layer *c*, which are thicker and more branched. In the hollow pillars, *e*, these tubes are uniformly parallel, radiating inwards. As in *Megalichthys*, all the tissues in the plane of and above the small inosculating tubes *i*, consist of kosmine, excepting the thin superficial layer of ganoin.

The tissues surrounding the Haversian canals, which are rather large, are osseous, presenting the same appearances as those of *Megalichthys*. The inferior laminæ of the scale also are horizontal and parallel, presenting the characteristic fusiform or linear lacunæ represented by fig. 19.

A vertical section of another scale already alluded to, also from Leeds, slightly differs from the last. The upper layer of the kosmine is thicker, and from the vertical cavities entering it but a small distance before giving off the inosculating tubes, 20 *i*, it would be impossible by any horizontal section to exhibit the elegant rings seen in 20 *e*. The Haversian canals are more like the large cancelli in the diploe of bone, and the branches which they send up into the kosmine are equally large; illustrating the description given of the development of the scale of *Megalichthys*.

Holoptychius.—The structure of some scales from the old red sandstone, belonging to this genus, has been already described by M. Agassiz*. His results, however, differ in many material points from those obtained by my own observations upon scales belonging to the same genus from the upper coal-measures of Lancashire, where at least two, if not more, species exist, which have hitherto been confounded under the name of *H. sauroides*.

These scales vary from being nearly orbicular to being so elongated, that their larger diameter becomes three or four times greater than the opposite one. In all cases one extremity is more pointed than the other, the latter being not unfrequently cordate. Their inferior surface is usually the only one seen, the upper one being adherent to the matrix. Fig. 21 represents the usual aspect of the latter, and fig. 22 of the former, amongst the larger scales of *H. sauroides*. Both surfaces exhibit the concentric lines noticed by M. Agassiz as "répétant les contours de l'écaille." These are the most beautifully regular and definite on the upper surface, especially at its anterior extremity, 21 *a*, but towards the pointed end, *b*, they give place to others of a larger size, but which are less numerous as well as less regular in their distribution. When the scale was *in situ*, the latter occupied the exposed portion, the remainder being covered over by the pointed extremities of the two scales in front of it; these con-

* Poissons de Vieux Grès Rouge, p. 70, tab. 24, fig. 10.

centric ridges are traversed at the two extremities, but especially at the posterior one, *b*, by minute radiating lines; at the two sides of the scale they are not visible. On the inferior surface the concentric lines extend over two-thirds of the scale, fig. 22, but they are less regularly definite and uniform in their thickness than on the opposite side. We find none of the radiating lines which M. Agassiz noticed in the corresponding portion of the scales from the old red sandstone, but its acuminated extremity, 22 *a*, corresponding to 21 *a*, exhibits a number of large puncta, 22 *c*, which are the orifices of ascending canals. On making a vertical section of one of these scales, I found few traces of either kosmine or ganoin; it consisted of numerous lamellæ, the lower ones resembling those seen in the corresponding portion of Megalichthys. These are shown in fig. 23 *a*, which represents a vertical section of a large scale, taken in the direction of the dotted line *c* in fig. 22. These lamellæ are furnished with lacunæ and canaliculi like those of *Megalichthys* and *Diplopterus*, fig. 19. The upper portion of the scale consists of the upturned lamellæ, which by their inflexions form the ridges which ornament its external surface, 23 *b*. In the section represented in the Plate, these ridges are less striking and prominent than ordinary; generally, instead of the section presenting a gently undulating outline, these ridges are irregular and even overhang the furrows which separate them, but still consist of the inflected extremities of the lamellæ, as do also the fine radiating lines of fig. 21.

Under these ridges, at the anterior part of the scale, we find a series of concentric canals, connected together by short anastomosing branches. They do not follow any very uniform direction in their distribution, varying considerably in the details of their arrangement, always however showing a tendency to be regulated by the direction of the lamellæ themselves, they having evidently been formed on the principle seen in the scale of the Sturgeon: thus in the section fig. 23, we find that many of the branches of these canals exhibit a curvilinear arrangement, 23 *c*, their direction corresponding with that of the lamellæ. From these Haversian canals are given off numerous vertical branches, especially at the acuminated extremity of the scale. Those which ascend, open in the grooves separating the concentric ridges, fig. 23 *d*, whilst the orifices of the descending ones produce the puncta seen at fig. 22 *c*. These vertical canals have not been formed by inflexions of the lamellæ, but by the leaving out of the apposite portions of each succeeding lamella as it was organized; consequently they merely pass through the latter nearly at right angles to their plane.

The whole texture of the scale is crowded with various modifications of lacunæ, from the fusiform ones already described to those of the ordinary ichthyal type; and though many of their canaliculi traverse the lamellæ, they are chiefly developed parallel with these layers, and follow their direction.

In the species examined by M. Agassiz, that philosopher found a structure very similar to the one just described; he applies the term enameled (*émaillée*) to the layers constituting the external ornaments of the scale, at the same time however observing, that they are "qu'une substance osseuse plus épaisse, dans laquelles les

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couches sont effacées, et les corpuscules plus grandes." M. Agassiz also notices radiating lines crossing the concentric ones, but he describes them as "formées par de petits canellures très fines et à peine en relief, dans lesquels se fixaient probablement les fibres de la peau." In *H. sauroides*, as we have seen, the inferior surface exhibits none of these lines; and in the upper layers the lamellæ are not effaced, though the structure is dense. I have not unfrequently observed, in some of the projecting ridges, a slight disposition towards the development of kosmine tubes, as if nature was making her earliest efforts at converting the true osseous lamellæ into kosmine.

The preceding description, which applies to the majority of the scales of Holoptychius which I have examined, reveals to us many points of remarkable identity between them and those of *Megalichthys* and *Diplopterus*, indicating a much closer affinity between these three genera than has hitherto been recognised. The examination of one oblong scale belonging to an undoubted species of *Holoptychius* from the upper coal shales of Lancashire, establishes this affinity still more strongly. Its inferior surface exhibited the same appearance as *H. sauroides*; smooth concentric lines existing at its rounded extremity, whilst the acuminated one was studded with large puncta. But on making a vertical section, a striking difference presented itself in the superior surface, which, being adherent to its matrix, could not previously be seen. The rounded extremity exhibited the structure seen in the corresponding part of *H. sauroides*. The inferior layers of the opposite extremity also correspond, fig. 24 *a*. The puncta open into ascending canals, which perforate the laminæ, 24 *b*, and communicate superiorly with a system of canals or cavities, 24 *d*, analogous to those of the *Diplopterus*, fig. 20 *d*, to the appearance that would be presented by a vertical section of which this form of *Holoptychius* forms an excellent illustration. Above and around this superficial cavity, 24 *d*, is a development of kosmine, which is penetrated from above by trumpet-shaped cavities, 24 *e*, and which give off small connecting tubes, 24 *f*, transverse sections of which, coming from the more distant cavities not cut across by the section, are seen at *g*. These trumpet-shaped cavities are not quite so gracefully formed as in *Megalichthys*, but in other respects they are very similar. After giving off these tubes, the cavities spread out continuously in every direction over the osseous tissue, and send up into each areola formed by the network of tubes, an expansion, 24 *h*, analogous to the cul-de-sacs of *Megalichthys*, but which, instead of being isolated as in that genus, in the mature state of this *Holoptychius* all open into one another, as seen at the extremity of the scale, *d*; the only connecting portions between what may be regarded as the roof and the floor of this space being the hollow pillars surrounding the cavities, *e*. As in *Diplopterus*, the whole of the kosmine receives its minute tubuli from this large superficial space, from which they radiate in every direction.

This section also explains what has been already said respecting the growth of the kosmine in *Megalichthys*. Its permanent structure in *Holoptychius* presents the condition which has obviously existed in the young state of the scale in that genus. On

comparing figs. 15 and 24 together, and bearing in mind the concentric lines in the kosmine of the former, this identity will be obvious at a glance; and it will be seen how the addition of successive lamellæ to such a framework as fig. 24 exhibits, would lead to all the results which we find in *Megalichthys*, and also establishes the close connection that exists between the two genera, as well as between them and *Diplopterus*; instead of one being found amongst the Cœlacanths, and the other two amongst the Sauroids, this resemblance, connected with the close analogy existing between their teeth and such fragments of bone as have been met with, requires that they should in future be classed side by side.

No doubt can exist that in these species of *Holoptychius*, the bony lamellæ have been deposited on the same plan that we have found to prevail throughout all the forms of scale which I have examined. This is especially seen in fig. 23. The existence of the Haversian canals can be distinctly traced, either to the inflexions of these lamellæ, or to the leaving out of portions of them, as in the case of the vertical branches.

Bearing in mind the close affinity just noticed, between the genus under consideration and *Megalichthys*, we can scarcely suppose it probable that their scales have been constructed on two widely different physiological plans. That of *Holoptychius* appears to be intermediate, as to the complexity of its structure, between those of *Acipenser* and *Megalichthys*; consequently we can scarcely resist the conclusion, to which the study of the latter fish alone has led me to incline, that complicated as its scales are, they have been formed, *ab initio*, on the same plan of intramembranous ossification as all the rest.

Judging from the descriptions given by M. Agassiz, it appears evident that a recent example of a scale somewhat similar to the type found in *Holoptychius*, occurs in the *Polypterus* of the Nile. Though in his description M. Agassiz does not notice anything analogous to the forms of kosmine described in the last genera, yet in the horizontal network of canals, and their vertical branches communicating with both the upper and lower surfaces, we have an analogy too evident to be overlooked; and one which attracted the attention of the Swiss philosopher, whilst examining some of the *Diplopteri* from the old red sandstone. It is highly interesting to find, that, though we have so small a number of ganoid fish still existing, when compared with the multitudes which crowded the ancient seas of our globe, we have, in the Bony Pike, the Sturgeon and the Polypterus, living representatives of the most conspicuous types of scale-structure found amongst their fossil allies.

Macropoma.—This anomalous genus has long been a source of perplexity to ichthyologists. *Macropoma Mantelli*, first discovered in the Sussex chalk by the distinguished geologist whose name it bears, was first arranged by M. Agassiz amongst the sauroid subdivision of the ganoid fish. He afterwards removed it to the Cœlacanths, and still more recently he has proposed to unite it with the genus *Undina* of Munster and some others, of which he designed to form a new group*. On

* Poissons Fossiles de Vieux Grès Rouge, p. 61.

examining a portion of the opercular scale of this fish, I found it to be studded over with tubercles, fig. 25 *a*, like those in a piece of shagreen. On grinding away the under surface, so as to render the upper part transparent, there appeared beneath each tubercle a large lenticular cavity, fig. 25 *b*, which, as we shall subsequently show, is homologous with the pulp-cavity of the dermal teeth of placoid fish. From each cavity is given off a number of small tubular canals, fig. 25 *c*, which radiate outwards and upwards, and communicate with the external surface of the scale. The posterior portion of each tubercle, 25 *d*, is more prominent than its opposite extremity, evincing a disposition to become pointed and grooved on its surface. The tissue surrounding the bases of these tubercles is studded with numerous lacunæ and a few scattered points, 25 *e*, constituting the orifices of canals which come up from below. On making a vertical section of the specimen, fig. 26, I found that the tubercle surmounting each cavity, fig. 26 *a*, was composed of kosmine with exceedingly fine branched tubes, 26 *b*, radiating from the cavity, 26 *c*, and covered over with and merging in a layer of transparent ganoin, 26 *d*, which on its posterior margin exhibited the irregular superficial grooves already noticed. The kosmine consisted of a number of very dense but still distinct lamellæ, arranged in concentric lines, which, superiorly, followed the curved outline of the tooth, and inferiorly, that of the roof of the subjacent cavity. Beneath each tubercle is this lenticular pulp-cavity, figs. 25 *b*, 26 *b*, the radiating prolongations of which, 25 *c*, 26 *e*, proceeding upwards and outwards, form channels of communication with the external surface, reminding us of those existing in connection with similar tubercles on the scale of *Dapidius granulosus*.

The textures which give support to these tooth-like appendages, consist of a series of osseous laminæ, fig. 26 *f*, which are again subdivided into numerous minute lamellæ. Amongst the inferior laminæ are a number of very large cavities, which run into each other by means of narrow connecting passages, forming the homologues of Haversian canals, fig. 26 *g*. They send up narrow vertical branches to the external surface, which generally open at the small apertures, 25 *e*, but occasionally unite with one of the canals radiating from the lenticular pulp-cavities, fig. 26 *h*.

The lowermost osseous laminæ are not so thick, individually, as the upper ones, but they are more regularly uniform in size, as well as more parallel with the inferior surface, and with one another.

Between the lamellæ is a copious distribution of lacunæ, many of the canaliculi of which radiate vertically as well as horizontally, perforating the lamellæ, and thus establishing a communication between contiguous layers of lacunæ.

The specimens which I have had the opportunity of examining exhibited no trace of upturned lamellæ in any part of their course, though their inflexions appear to have formed the large Haversian cavities, fig. 26 *g*. It is possible, however, that they may do so at the margin of the operculum, a portion which I have had no opportunity of investigating, and which requires further attention.

In addition to the canaliculi of the lacunæ, we also find a considerable supply of

what appear to be lepidine tubes, ascending from the inferior surface to the uppermost layers of the structure, fig. 26 *k*.

The general aspect of the exterior of the body of *Macropoma Mantelli*, is that of an ordinary scaled fish. This is especially shown in a fine specimen, formerly in the collection of Dr. Mantell, and now in the British Museum; originally figured by that gentleman in his work on the Fossils of the South Downs, and afterwards by M. Agassiz*. Specimens exhibiting the exterior of the fish are very rare, since, owing to the roughness of the outer surface of the scales, they are usually adherent to the matrix, the inner portion being exposed; or, what is even more frequently the case, each scale has split horizontally, and only exhibits its internal tissues.

According to the enlarged figures of M. Agassiz†, the anterior part of the upper surface of each scale is marked with concentric lines, which he regards as lines of growth; whilst the posterior or visible portion is crowded with elongated tubercles, or pointed cylinders; those on the centre of each scale being the largest. On making a very careful examination of the surface of these scales, I found that the tubercles, the "cylindres pointus" of Agassiz, were dermal teeth, corresponding with those already described as existing on the opercular scale; instead however of being nearly orbicular as in that example, they are all more or less elongated, whilst some of them, and especially four or five large ones ranged along the middle of many of the scales, stand up in bold relief, appearing like well-defined pointed teeth, equal in their degree of development to any which I have seen in the skins of recent Placoids. The pulp-cavity is similarly elongated, still however giving off the radiating canals at its base. These latter frequently communicate between one cavity and another.

Each of the teeth is irregularly grooved on its external surface, and these grooves, being prolonged in irregularly parallel lines on the broad thin expansions into which the bases of the teeth spread out, give to them somewhat the appearance of concentric striæ. In none of those which I have seen have I been able to discover the regularly concentric arrangement shown in the figures of M. Agassiz. Plate XLIII. fig. 27 represents a vertical section of the greater part of a scale in which the tubercles are very small, but in which the lower tissues appear to be complete; 27 *f* is the posterior extremity of one scale resting upon the anterior margin, 27 *g* of another; a small portion of the posterior extremity of the latter is still wanting.

The textures exhibited in this section are divisible into two portions, an upper and a lower one. The former, fig. 27 *a*, is of a dense structure, and appears mainly to consist of the expanded bases of the tooth-like tubercles in which some few lacunæ are developed. In this the tubercles are implanted, 27 *b*, each of which corresponds in its general structure with those already described from the opercular scale, fig. 26 *a*, only in this instance they are more depressed, and the pulp-cavity is larger in proportion to the size of the tubercle. The concentric lamellæ of the kosmine are also seen completely to surround the pulp-cavity, being continuously developed to some extent be-

* Poissons Fossiles, vol. ii. tab. 65 *b*.

† *Ut supra*, tab. 65 *b*.

low as well as above it. Similar canals communicate between the pulp-cavity and the upper surface, fig. 27 *d*. Beneath this superficial tissue we find another structure, composed of numerous thin parallel lamellæ, which gradually ascend as they proceed from the anterior towards the posterior margin of the scale, fig. 27 *e*; and upon the outcropping edges of which, to employ a geological illustration, the more superficial layer rests in unconformed stratification. No true lacunæ appear to enter into the structure of these lamellæ, but between them are layers of small irregular tubes, which anastomose freely with one another; those found on opposite sides of each lamella, like the fusiform lacunæ of *Megalichthys*, usually running in different directions, so as to give to the horizontal section the aspect of network. These do not appear to be modified lacunæ, but seem more analogous to lepidine tubes. They give off numerous branches, which pass through the lamellæ, keeping up a communication between contiguous layers.

Fig. 28 is a section of one of the rows of large teeth from the centre of the scale. In this specimen, from which the lower laminæ have been accidentally detached, as is usually the case, the tubercles are developed into the form of regular pointed dermal teeth, each having a pulp-cavity, fig. 28 *a*, from which spring small branching tubes, 28 *b*, like those seen in the dermal teeth of ordinary Placoids. Each one exhibits a laminated structure like that seen in the true teeth of reptiles, the lamellæ being arranged as a succession of cones, having evidently been formed by the addition of new internal layers organized around the soft pulp. In fact, it is only one of the laminated tubercles of the operculum, fig. 26 *a*, drawn out vertically; the lenticular space, fig. 26 *c*, being also elongated in the form of a true pulp-cavity, whilst, in consequence of this modification of the external contour, the lamellæ have assumed the appearance of a succession of cones inclosing each other. At the base of each tooth we still find the radiating canals, fig. 28 *d*, communicating with the exterior of the scale, as in those of the operculum.

Fig. 28 *e* represents the externally grooved appearance of each tooth, the section not having passed completely through its centre.

The most extraordinary feature in the anatomy of this singular fish yet remains to be described. In its interior there is invariably found a long hollow fusiform viscus, which has generally been regarded as a stomach. M. Agassiz, who entertained this opinion, says, "Il ressemble à un cylindre squammeux, et cet aspect est évidemment le résultat des changemens survenus dans les différentes membranes qui en composaient les parois."

On mounting prepared sections of this "membrane," I found that it consisted of true laminated bony tissue. When a vertical section was made through its entire thickness parallel to the long axis of the viscus, it presented the appearance represented in fig. 30. It chiefly consists of horizontal lamellæ, fig. 30 *a*, between which are developed large lacunæ, fig. 30 *b*, identical with those found in the bones of its

endo-skeleton. These lacunæ not only distribute their large canaliculi in the plane of the lamellæ, but shorter vertical twigs penetrate the lamellæ, and thus keep up a communication between the inner and outer surfaces of the viscus.

Some of the external lamellæ lose their exact parallelism with those below, and one in particular assumes an undulatory arrangement, fig. 30 *c*, in the folds of which, alternately above and below, are placed large irregularly-shaped lacunæ, fig. 30 *d*, the distorted prolongations from which are obviously modified canaliculi. This curious structure is covered over with other more dense and apparently structureless lamellæ, which fill up the inequalities and restore the parallelism of the surface with the lower lamellæ, constituting the exterior of the viscus.

On examining a horizontal preparation of a fragment of the same viscus, we see that the undulations of the lamella, fig. 30 *c*, produce the appearance exhibited by fig. 29. Numerous parallel lines enclose corresponding spaces, about the $\frac{1}{1200}$th of an inch in width, which circumscribe the viscus at right angles to its longer diameter. The lacunæ, fig. 29 *a*, which are arranged in corresponding rows, are alternately above and below the lamella, their irregularly projecting canaliculi, 29 *b*, giving them the aspect of Hebrew or Arabic characters. On making a horizontal section amongst the lower lamellæ, 30 *a*, we find that the numerous lacunæ are of the common ichthyal type, only they are more than usually crowded together, as well as anastomose more freely through their spider-like lacunæ. No canals of any kind pass through the tissue. These facts of course do away with all probability of this anomalous viscus having been a stomach; according to Dr. MANTELL, to whom we are indebted for the discovery of this singular creature, the broad anterior extremity of the cylinder is always open, and situated opposite the posterior margin of the opercular bone, whilst its caudal termination is as invariably closed.

I am disposed to believe that it has been an organ fulfilling the functions of an air-bladder. Its osseous structure would render it capable of resisting a considerable amount of pressure, and if its patulous extremity has been closed up by an elastic membranous appendage, capable of acting as a valve, this would enable the creature to regulate its buoyancy by increasing or diminishing the compression of the contained air, and thus facilitate its movements in either shallow water or at great depths. Except in cases of diseased ossification, the existence of an internal thoracic or abdominal viscus, having hard parietes of true bone, is an anomaly, which, as far as I am aware, has hitherto presented no parallel in nature.

The structure of the scale of *Macropoma*, as now described, is wholly different from that presented by any of the ganoid fish noticed in the preceding pages. It bears a much closer resemblance in its leading points to the dermal appendages found amongst the group of true Placoids, between which and the Ganoids the *Macropoma* appears to form an inosculating link. In order to illustrate this opinion, I have accompanied the memoir by figures of portions of the dermal appendages of

one or two Placoids, which will enable us better to comprehend the structure and affinities of this singular creature.

Fig. 31 represents a thin horizontal section of the shagreen or skin of the Dog-fish. It consists, as is well known, of a number of small dermal teeth, implanted in a more or less linear manner in a soft skin, figs. 31 *a*, 32 *a*. Each tooth contains a pulp-cavity, fig. 31 *b*, from which radiate several large canals. One of these descends vertically, as seen in fig. 32 *b*, which represents a vertical section of an individual tooth. The remainder, varying in number from one to three or four, proceed in a horizontal direction towards the posterior portion of the tooth, figs. 31 *c*, 32 *c*, where they appear to communicate with the most superficial layers of the integument, if not with the external surface itself, being apparently the analogues of the radiating canals in the tubercles and teeth of *Macropoma*, figs. 25 *c*, 26 *e*, 27 *d* and 28 *d*.

From each pulp-cavity is also given off numerous branching tubes like those seen in the dentine of the teeth of sharks. They only differ from those in the corresponding dermal teeth of *Macropoma* in being larger and less crowded together.

The superficial portion of each of these appendages, which is not imbedded in the soft cutaneous tissues, is covered over with a very thin layer of glossy ganoin, but between which and the tubular structure there is no distinct line of demarcation.

If we compare these vertical and horizontal sections of the dermal teeth of the Dog-fish, figs. 31 and 32, with the corresponding representations of the operculum and scale of *Macropoma*, figs. 25, 26 and 28, we cannot fail to be struck with their identity in every respect. The only real difference appears to be, that, whilst in the Dog-fish the teeth are isolated, being implanted in a soft integument, in the *Macropoma* they are fixed upon a calcareous basis. In the case of the operculum, this basis consists of a true osseous structure; and in the scales, though the true bony matter has dwindled down into the thin superficial film surrounding the bases of the teeth, its place is supplied by a thin laminated tissue which is its equivalent, as a solid foundation on which numerous teeth are aggregated, and which is probably but the homologue of the thin laminæ of which the stellate bases of the dermal teeth of many Placoids are composed.

If these are true analogies and not mere resemblances, they afford us an interesting illustration of the successive steps in the development of the hard cutaneous covering seen in the ganoid fish: but before endeavouring to trace this development, I would direct attention to an additional link in the chain supplied by the fossil shagreen of the *Hybodus reticulatus*, from the lias of Lyme Regis; a vertical section of which is represented in fig. 33.

We here find another modification of the dermal teeth, fig. 33 *a*, with large pulp-cavities, 33 *b*, and canals opening laterally as well as vertically, 33 *c*, communicating with the soft tissues in which the teeth have been originally implanted. From these pulp-cavities, also radiate branching tubes resembling those of dentine. So far, there

is no material difference between these and the dermal teeth of the Dog-fish; but beneath them, and imbedded in the soft tissues of the true skin, we find a vast number of small, irregular calcareous nodules, 33 *d*, each of which consists of a series of concentrically arranged lamellæ. They contain neither lacunæ nor visible tubes, but frequently exhibit small brown points, which however may merely be some effect of their subsequent mineralization. Though not composed of true bone, these are surely to be regarded as a rudimentary attempt at the extension, amongst the Placoids, of that calcareous exo-skeleton which has received so complete a development in the ganoid fish.

We may now for a moment retrace our steps and endeavour to mark some of the successive stages in the development of this portion of the exo-skeleton.

In the common Thornback, *Raia clavata*, Cuv., a long central row of dermal teeth extends from the head to near the extremity of the tail. They exhibit the tubular structure found in this class of objects, but contain very little calcareous matter; they are scarcely more solid in their structure than the cartilaginous column which they surmount. The skin of the same fish is studded over with still more minute teeth, but which contain much more earthy matter: we have however no trace of true bone. Each dermal tooth consists of a succession of conical lamellæ placed one upon another; the apex, which rises above the cuticle, resembles that of the Dog-fish in structure; inferiorly, these lamellæ expand into a stellate base, in which portion they are much less consolidated, considerable spaces occasionally existing between individual layers after they have been artificially dried. The pulp-cavity is quite open inferiorly, there being no extension of the lamellæ across its base, and consequently no necessity for the horizontal canals, which are wanting. In the shagreen of the Dog-fish we have an advance upon this structure. The lower tissues are more consolidated, and present an extension of the lamellæ across the base, closing in the pulp-cavity as already described, and being only perforated by the narrow canals, fig. 32 *d*. In *Hybodus reticulatus* we find dermal teeth of a similar type to those of the Dog-fish, but we have a further development of calcareous granules in the subjacent skin, but no true bone. In *Macropoma* we advance still further. In each scale we find a laminated texture, probably analogous in its nature to the expanded bases of the teeth in the shagreen of the Thornback: upon this texture, the teeth, no longer isolated, are aggregated; whilst on the surface of the scale thus formed, we find, for the first time, a thin film of true bone. In the operculum of *Macropoma*, the substructure upon which the dermal teeth are implanted exhibits all the essential characters of true bone, its laminated structures preparing us for the ganoid fish, where not only the operculum but also the other scales are of an osseous nature. Amongst these we still find scattered dermal teeth, studding the scales of *Dapidius granulosus*, presenting the same external contour, internal pulp-cavity, branching tubuli and canals communicating with the exterior as in the preceding forms.

These successive steps, conducting us from the dermal appendages of the Placoids

to the ganoid scales, indicate a series of analogies which can scarcely be questioned. But I should even venture to go still further; I can trace no real difference between the tubercles of the scale of *Dapidius granulosus*, and what I have called the kosmine, in *Lepidotus* and its allies. The latter appears to me to be only a more extended development of the former. In the beautiful form in which this kosmine exists on the scales of *Megalichthys*, *Diplopterus* and *Holoptychius*, we have nothing more, apparently, than the confluent aggregation and superficial depression of a number of placoid teeth, surmounting a highly developed bony scale. Compare for a moment the horizontal section of the shagreen of the Dog-fish, fig. 31, with the horizontal section of the *Diplopterus*, fig. 20. The dermal teeth of the former are represented by the areolæ of the latter; the pulp-cavity and branching tubes of the true dermal tooth, fig. 31 *b*, have their homologues in the ascending central cavities and branching tubes of the areolæ of the *Diplopterus*, fig. 20 *m*. In the same way the ascending cul-de-sac in each areola of the *Megalichthys* appears to correspond with the pulp-cavity, whilst the arborescent tubuli which it gives off represent the dentine-like tubes of the shagreen. The chief difference appears to consist in the fact, that in the Ganoid, the areolæ, being closely aggregated upon a bony basis, have coalesced, and been flattened, superiorly, to an uniform level; whilst in the Placoid, each areola forms an isolated conical tooth, implanted in the soft integument. The different degrees to which the same structure may be either flattened, or drawn out and become acuminate, is seen in the various parts of the exo-skeleton of *Macropoma*, showing that the process is a very trivial one, involving no typical change*.

* Since the above remarks were penned, I have found a still more beautiful illustration of this homology. When the smooth shining membrane covering the snout of the Saw-fish is examined under the microscope, it is found to consist of a thin soft skin, in which are implanted numerous flattened dermal teeth, each resembling, in its form, the small studs commonly worn as breast-ornaments. They are packed closely together, with only a few minute intervening spaces. This closely aggregate arrangement, combined with their depressed form, causes the whole to present a smooth, shining surface, nearly resembling that of a ganoid scale. Fig. 34 represents a vertical section of some of these teeth with the subjacent tissues; 34 *a* is the upper portion of the osseous (?) structure of the snout; *b*, the soft integument; *c*, individual teeth; *d*, the pulp-cavity; *e*, canals radiating from the latter, from four to eight existing in each tooth, and arranged as in *Macropoma*, fig. 25; *f*, descending canal, communicating between the pulp-cavity and the subjacent soft integument; *g*, dentine-like (kosmine) tubes; *h*, open spaces surrounding each tooth, and appearing, when viewed vertically by transmitted light, like a network of canals, reminding us most forcibly of the similar appearance surrounding each areola in *Megalichthys*, fig. 16. Where three or four of the teeth meet there is usually a minute space not filled up, opening into this network, which latter is formed by the horizontal constriction of the teeth, as seen in 34 *i*, which represents the exterior of an individual which the section has not divided.

On comparing this section with the vertical one of *Megalichthys*, fig. 15, the homologies of the various parts are still more striking than in the example of the Dog-fish. Each tooth in the Saw-fish represents one superficial areola of the *Megalichthys*. The small superficial intervals between the teeth appear to be the homologues of the descending trumpet-shaped cavities, 15 *a*; these communicate between the exterior and the interdental spaces, 34 *h*, which apparently correspond with the network of small tubes in *Megalichthys*, 15 *c* and 16 *c*, as already observed. The pulp-cavity, 34 *d*, takes the place of the cul-de-sac, 15 *f*, a communication being maintained between the interdental spaces and these pulp-cavities, by means of the radiating canals, 34 *e*. And, as

This supposed analogy is, in some degree, supported by the resemblance in the process by which the areolæ of *Megalichthys* and the dermal teeth of the Placoids are developed and increased. In both examples it is by the addition of new internal layers around the central cavity. The same is the case in the tubercles and teeth of *Macropoma*. These facts (if correctly interpreted, and I believe them to be so) confirm the necessity of my proposed restriction of the terms ganoin, enamel (*émail*), &c. Two perfectly distinct structures have hitherto been comprehended in the expression "enamel," as hitherto applied to the scales of fish, viz. the superficial, transparent, hyaline tissue, which usually gives glossiness to the surface of the scale, and a subjacent one, which I propose to distinguish by the name of kosmine*. In some genera, such as *Megalichthys*, this latter structure is gradually blended with the former, the line of demarcation not being visible; whilst in others, such as *Lepidotus*, *Palæoniscus* etc., it is perfectly distinct from it, blending rather with the subjacent osseous tissue. These two appear to be as distinct as bone and dentine. The ganoin exhibits no visible trace of structure beyond its arrangement in the form of laminæ, and the occasional existence of minute coloured granular points. When separated from the tissue upon which it rests, it evinces a marked disposition to crack and splinter in every direction. The kosmine, on the other hand, in a fossil state at least, is usually coloured, and always exhibits some arrangement of minute branching tubes, resembling those of dentine; and as, in some species of fish, Prof. Owen has pointed out the direct passage of Haversian canals into the pulp-cavities and dentinal tubes of the true teeth, so in the kosmine do we find a direct extension of the similar canals into the corresponding tubular structures of the surface of the scale.

I have seen no instance in which this kosmine has been present without a covering of ganoin, whilst the latter may frequently be present without any subjacent kosmine. I am further led to conclude, that, whatever name be ultimately employed to represent what I have designated kosmine, it must also be applied to those dentine-like tissues, which, in the form of dermal teeth, ornament the skins of so many Placoids.

If then I am correct on these points, we must come to the conclusion, that, whilst the scales of many of the so-called "Ganoid" fish, such as the Sturgeon, and other similar forms, exhibit few or no traces of either ganoin or kosmine, many of the "Placoids" exhibit such an extensive development of both, as finds few parallels amongst the Ganoids; so that, not only have we several connecting links merging the two groups in one another, more of which links doubtless remain to be discovered, but the distinction of "Ganoid," as the term has hitherto been applied, ceases to be a physiological one.

in *Megalichthys* each cul-de-sac communicates with the subjacent tissues through the medium of the Haversian canals, so in the Saw-fish the descending canal, 34 *f*, communicates with the soft integument, *b*, which alone separates it from the curious cancellated structure, *a*, representing the bony (?) part of the snout. It is obvious that we only require the upper and lower disc-like expansions of contiguous teeth to become confluent, to give us a structure closely resembling that which covers the bony scales of *Megalichthys*.

* See page 442.

Another conclusion to be drawn from the foregoing observations, is the corroboration of a portion of the views of M. Agassiz in reference to the mode of growth which has obtained amongst the scales of "ganoid fish," viz. that it has been accomplished by the addition of new lamellæ applied to their exterior*: but these growths have not been confined to the lower surface; in some, as in *Lepidosteus*, *Acipenser*, and *Holoptychius*, they have partially covered the upper one also; whilst in others, as in *Lepidotus*, *Aspidorhynchus*, &c., the concentric circle has been made complete, superiorly, either by the addition of continuous layers of true bone or of ganoin. In either of the latter cases the newly-formed lamellæ have completely enclosed the older growths; consequently, though agreeing with M. Agassiz in the main, I can scarcely conclude, as he does, that "l'organe sécréteur est la poche épidermoidale dans laquelle elles sont enfoncées par leurs bords antérieurs." It is evident that each scale must have been completely and permanently surrounded by a kind of periosteum, closely embracing its entire circumference, and prolongations from which have entered many of the Haversian canals in such genera as *Megalichthys*, in the opercular bone of *Lepidotus*, and in *Macropoma Mantelli*. Though corresponding prolongations may have also entered the smaller parallel tubes of the *Lepidostei* and *Lepidoti*, we have no evidence that these latter prolongations possessed any secreting power, since no parallel lamellæ line their vertical walls; and in the same way, those portions which have lined the *vertical* Haversian canals of *Holoptychius* and the trumpet-shaped cavities of *Megalichthys*, do not appear to have secreted any solid tissues. This membrane has doubtless derived its supplies of blood from the soft integument, which has not only been in contact with the whole base of the scale, but also with the superior surface of its anterior and often lateral margin.

We also obtain from the history of these scales, some important evidence illustrating the process of bone-growth amongst the Mammalia. Most anatomists are aware that some new and highly interesting views have been advanced by Prof. Sharpey, who has shown that, in the case of each human bone, but a comparatively small portion of it had originated from the deposition of calcareous matter amongst the cells of true cartilage; all its subsequent increase in thickness or diameter proceeding from the calcification of the inner layer of the periosteum, whose fibres are always found to be in intimate connection with the osseous surface. According to this view, the Haversian canals have not necessarily originated in any previous arrangement of the cartilage cells, but mainly resulted from the inflexions of the intermembranous growths of bony lamellæ, formed in the substance of the periosteum without the intervention of any temporary cartilaginous structure: and as an additional sequence, it becomes probable that the lacunæ and their canaliculi had resulted neither from a modification of the cartilage cell, as is believed by Schwann and Henle, nor of its nucleus, the view entertained by Mr. Tomes†; but rather that they are little vacuities

* See page 437.

† See Todd and Bowman's Physiological Anatomy, p. 119.

that have been left out, during the deposition of the membranous lamellæ and their subsequent impregnation with calcareous matter*.

The appearances presented by the scales described in the preceding pages, go far to confirm these views. I have not been able to detect the slightest trace of cartilage cells in either the recent scales of the Sturgeon and Lepidosteus, or in the dermal teeth and plates of any of the Placoid fish. The decalcified scales of the Sturgeon and Lepidosteus, show that the lime is deposited in a granular form, in the minute interstices of membranous lamellæ, and that, consequently, the origin of the magnificent lacunæ with their largely developed canaliculi, must be explained without having recourse to the intervention of cartilage cells, either in producing the cavity or influencing its position in the bone.

In the same way, the gradual progression to be observed as we pass from the simple laminated scale of *Seminotus* and *Lepidotus*, to the complicated development of Haversian canals existing in *Acipenser*, *Holoptychius* and *Megalichthys*, illustrate how the periosteal laminæ thickening the exterior of the shaft of a mammalian bone, may have been twisted and inflected; their undulations producing, first, grooves on its surface, and subsequently canals, from the arching over of the grooves so formed, by the corresponding but inversed inflexions of the more newly-formed lamellæ: whilst in some cases, as in *Megalichthys*, we find, what is less evident in the Sturgeon, that after these canals have been thus constructed, additional and more completely concentric lamellæ have been deposited within each canal, at once diminishing its diameter and thickening its walls.

We also obtain an additional illustration of what the study of comparative anatomy so frequently reveals, viz. the unequal degree in which the various portions of an organized structure are developed, in reference to the homological type of each. Thus, whilst in *Lepidosteus osseus* we have one of the simplest forms of the laminated scale, associated with vertebræ exhibiting the ball-and-socket-joint of the Ophidians, and teeth approximating to a Saurian form, in *Megalichthys* and *Holoptychius* we have scales mainly consisting of a complicated arrangement of Haversian canals, and abounding in long fusiform lacunæ, of the true reptilian type; whilst the vertebræ of *Holoptychius*, certainly, and I believe of *Megalichthys* also, present the double concave articulation ordinarily found in fishes and enaliosaurs.

The further carrying out of this investigation into the microscopic structure of the scales of fish, will afford an important means of distinguishing different fossil species, and also, when prudently employed, of establishing their affinities and alliances; but at the same time I would venture to caution the palæontologist against expecting too much from it. In many cases it will enable us to decide that two imperfect fragments belong to distinct species, and also to form a pretty correct judgment as to the general nature of each; but in numerous other instances, even very different genera

* Dr. Quain's Anatomy, 5th edition, by Dr. Sharpey and Mr. Quain, part 2, p. cxxxii. *et seq.*

of fish may present but a small and inappreciable amount of difference in the microscopic structure of their scales: thus, for example, a longitudinal section of the scale of a *Gyrodus* exhibits a much closer *apparent* analogy to that of an *Aspidorhynchus* than to that of the more closely allied genus *Platysomus*; though a close typical resemblance assimilates it to the latter. The uncertainty of this result is also increased by the various effects produced by the mineralization of the fossil scale. I have examined scales from some specimens of *Lepidotus semiserratus*, in which I had the greatest difficulty in detecting traces either of the beautiful arborescent tubuli or of the lacunæ shown in fig. 4, they having been almost, though not altogether, obliterated by the process of fossilization, teaching a lesson of caution, which the student will do well to remember. But notwithstanding these difficulties, the value of the inquiry, as furnishing us with an instrument which will facilitate the identification of affinities, is considerable, provided it is not made the *sole* standard of classification, but employed in conjunction with an equally minute examination of every other portion of the animal organism.

It now only remains for me to acknowledge the great kindness with which Sir Philip M. De Grey Egerton, Bart., M.P., Dr. Mantell, Mr. Binney, Mr. John Edward Gray and Mr. Searles Wood, have afforded me every assistance in their power, by supplying me with many important specimens for examination which my own cabinet did not contain. To each of these gentlemen my warmest thanks are due for their most valuable cooperation.

APPENDIX.

Since the preceding memoir was placed at the disposal of the Royal Society, the continued kindness of Sir Philip Egerton has enabled me to examine specimens of the curious premaxillary bones of the *Cœlorhynchus*, obtained both from the London clay and from the tertiary beds of North America. They exhibit a form of kosmine which is alike new and interesting. I learn from Sir Philip Egerton that the rostral appendage of this fish is made up of two semi-cylindrical bones (see fig. 35 *a a*) inclosing a canal, which is double towards the base, but which becomes coalescent as it approaches the apex, of which latter portion, fig. 35 represents a transverse section. These bones are marked externally with longitudinal grooves and corresponding ridges, the latter being the external margins of a series of long cuneiform plates, which radiate from the centre to the circumference.

Fig. 36 exhibits a profile representation of three of these plates, showing their internal structure. Each plate is separated from its neighbour by a thin vertical network of small canals, fig. 36 *a*, which open, externally, along the narrow groove, fig. 36 *b*, separating the convex ridges. In the transverse section, the divided orifices of the canals constituting this network are visible, fig. 36 *c*, along the vertical line of demarcation between the segments. From each side of this line, vast numbers of

minute kosmine tubes are seen arching downwards and inwards towards the centre of the plate, fig. 36 *d*. Similar tubes also descend from the convex upper surface of each plate, 36 *e*. From the top to the bottom of the segment are also seen numerous arched lines of growth, which run parallel to the upper surface; these are best represented in the segment, fig. 36 *f*, in which I have omitted the kosmine tubes, in order to exhibit the lamellæ with more clearness. Running longitudinally through the centre of each plate are several narrow, depressed, semilunar canals, fig. 36 *g*, arranged at nearly equal distances from one another, and into each of which many of the kosmine tubes, coming both from above and from below, appear to open.

Fig. 37 represents a *horizontal* section of two similar plates; at 37 *a* we again see the orifices of the network of canals. Owing to the arched direction assumed by the kosmine tubes, this section divides them nearly at right angles at the central part of each plate, whilst it is almost parallel with their plane at each margin; hence, at 37 *b*, these tubes are seen very distinctly, whilst at 37 *c* rows of minute dots alone mark the position of their divided orifices. The latter do not always run in lines exactly parallel to the plane of the marginal canals, but they exhibit a strong tendency to do so. Fig. 37 *d* shows the direction taken by one of the semilunar canals, fig. 36 *g*.

It is very easy to trace the process of growth in this interesting structure, in which each plate or segment represents a tooth turned inside out. The first deposition of calcareous matter has been made in the form of a thin cylinder surrounding the central cavity, fig. 35 *b*. New lamellæ, perforated with minute apertures, have been formed upon this basis; the apertures in each lamella being arranged in exact juxtaposition with those of the contiguous lamellæ. The minute tubes thus formed have *at first* all opened at the external surface, but it will be readily seen, that, after the addition of many new lamellæ, owing to their arched arrangement, the tubes of adjoining plates would meet at the line of junction, fig. 36 *c*, and thus each segment would contribute to block up those of its neighbour, preventing them from receiving their proper supply of nutritious fluids. To obviate this difficulty, however, the network of minute canals, fig. 36 *a* and *c*, has been left open between contiguous segments. The orifices of the kosmine tubes open into these canals, and maintain a free communication with the surface through the row of small orifices seen in each superficial sulcus, fig. 36 *b*. Thus the nutrition of the tissues in the interior of each segment continues to be provided for. The use of the longitudinal canals, figs. 36 *g* and 37 *d*, is uncertain. They have probably contained some form of pulpy matter. No trace of true bone is seen in the entire structure, which consists wholly of kosmine. In this it bears a resemblance to the rays and dorsal appendages of the placoid fish. The kosmine breaks with a translucent and shining fracture.

It is difficult to conceive of any arrangement by means of which a stronger fabric could have been produced, than is exhibited in this cylindrical combination of long radiating plates. The true nature of the appendage itself, as well as that of the fish to which it belongs, is yet uncertain; but if it has been a weapon of defence, like the

snout of the recent Sword-fish, the creature must have proved, in no small degree, formidable to its congeners.

In all its details, the structure corroborates the conclusion arrived at in the preceding memoir, and shows not only a process of growth by the addition of lamellæ, similar to that already described, but also indicates further, that whatever may be the direction and distribution either of kosmine or lepidine tubes, the additions to the structure which they permeate are always made to the surface on which their largest apertures open; whether that surface be found in an internal cavity, as in *Megalichthys* and *Diplopterus*, or whether it is in their exterior, as in *Cœlorhynchus*.

Description of the Plates.

PLATE XL.

Fig. 1. Vertical section of a scale of *Lepidosteus osseus*, parallel with the lateral line of the fish. Magnified 8 diameters.

Fig. 2. Vertical section of the half of a similar scale, made at right angles to the lateral line. Magnified 14 diameters.

Fig. 3. Vertical section of the anterior border of a scale of *Lepidotus semiserratus*, parallel with the lateral line. Magnified 25 diameters.

Fig. 4. Horizontal section of the upper surface of part of the same scale. Magnified 112 diameters.

Fig. 5. Horizontal section of a tubercle from the surface of a scale of *Dapidius granulosus*.

Fig. 6. Vertical section of the same.

Fig. 7. Horizontal section of part of the surface of *Palæoniscus comptus*. Magnified 90 diameters.

PLATE XLI.

Fig. 8. Horizontal section of part of the surface of *Palæoniscus Beaumontii*.

Fig. 9. Vertical section of a scale of *Seminotus rhombifer*, made parallel to the lateral line.

Fig. 9*. Vertical section of a scale of a *Gyrodus* from Kellheim, parallel to the lateral line.

Fig. 10. Vertical section of *Aspidorhynchus acutirostris*, parallel to the lateral line. Magnified 16 diameters.

Fig. 11. Vertical section of part of a scale of *Acipenser Sturio*, parallel with the lateral line of the fish, and midway between the centre and the lower angle of the lozenge-shaped scale. Magnified 7 diameters.

Fig. 12. Vertical section of a scale of *Platysomus parvulus*, parallel with the lateral line. Magnified 80 diameters.

Fig. 13. Vertical section of the upper half of the same scale, made at right angles to the lateral line. Magnified 100 diameters.

Fig. 14. Horizontal section of part of the same scale, made in the direction of the line, fig. 12 *e f*.

Fig. 15. Vertical section of part of a scale of *Megalichthys Hibbertii*. Magnified 80 diameters.

PLATE XLII.

Fig. 16. Horizontal section of part of the surface of the scale of *Megalichthys Hibbertii*. Magnified 60 diameters.

Fig. 17. Vertical section of part of a scale of a small species of *Megalichthys*. Magnified 110 diameters.

Fig. 18. Vertical section of the lower part of a scale of *Megalichthys Hibbertii*, made at right angles to the lateral line. Magnified 10 diameters.

Fig. 19. Horizontal section of the laminæ, fig. 15 *i*, *Megalichthys Hibbertii*. Magnified 300 diameters.

Fig. 20. Oblique horizontal section of the upper part of a *Diplopterus*. Magnified 27 diameters.

Fig. 21. Upper surface of a large scale of *Holoptychius sauroides*, natural size.

Fig. 22. Inferior surface of the same scale.

Fig. 23. Vertical section of a scale of *Holoptychius sauroides*, taken in the direction of the dotted line, fig. 22 *c*. Magnified 30 diameters.

Fig. 24. Vertical section of part of the scale of a species of *Holoptychius*, made nearly in the direction of the line, fig. 22 *c*, only verging more towards the centre of the scale. Magnified 30 diameters.

Fig. 25. Horizontal section of the surface of the opercular bone of *Macropoma Mantelli*. Magnified 25 diameters.

Fig. 26. Vertical section of part of the same opercular bone, taken parallel to the lateral line of the fish. Magnified 70 diameters.

PLATE XLIII.

Fig. 27. Vertical section of parts of two scales of *Macropoma Mantelli*, made parallel to the mesial line. Magnified 25 diameters.

Fig. 28. Vertical section of a row of large dermal teeth, from the centre of a scale of *Macropoma Mantelli*. Magnified 18 diameters.

Fig. 29. Horizontal section of the surface of the internal osseous viscus of *Macropoma Mantelli*. Magnified 350 diameters.

Fig. 30. Vertical section of the parietes of the same viscus, taken in the direction of its long axis, and parallel to the mesial line. Magnified 350 diameters.

Fig. 31. Horizontal section of the shagreen of the common Dog-fish, the bases and apices of the dermal teeth being alike ground away. The faint ring surrounding each areola is produced by the form of the tooth; the upper section having divided it at a narrower point than the lower one, thus shows a portion of the surface of each.

Fig. 32. Vertical section of one of the dermal teeth of fig. 31.

Fig. 33. Vertical section of the fossil shagreen of the *Hybodus reticulatus*.

Fig. 34. Vertical section of the surface of the snout of the common Saw-fish (*Pristis*). Magnified 65 diameters.

Fig. 35. Vertical section of the premaxillary bones of a *Cœlorhynchus*. Natural size.

Fig. 36. Profile view of part of the same organism. Magnified 6 diameters.

Fig. 37. Horizontal section of portions of two segments of the same. Magnified 9 diameters.

XXIV. *On the Nitroprussides, a New Class of Salts.*

By Dr. Lyon Playfair, *F.R.S., F.C.S.*

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1. In an inquiry into the constitution of the prussides, I found it necessary to examine into the somewhat anomalous action of nitric acid on the yellow prusside of potassium. This examination has led to the discovery of a singular class of compounds, which form the subject of the present memoir.

The previous knowledge on the action of nitric acid on the prussides may be summed up very briefly. Thomson* examined the gases produced during the action, and recognized them to be nitrogen, cyanogen, nitric oxide, and carbonic acid, while the residue was believed to consist of pernitrate of iron and nitrate of potash. Döbereiner† remarked that previous to the complete decomposition of the prussides, a strong coffee-coloured liquid was produced, which, after neutralization, precipitated protosalts of iron of a dark blue colour. Gmelin‡, to whom chemistry was already indebted for important discoveries in the prussides, observed that the coffee-coloured liquid noticed by Döbereiner was rendered of a magnificent purple or blue colour on the addition of an alkaline sulphide. The same fact was noted by Mr. Mercer§ of Oakenshaw, without his being aware that it had already been remarked by Gmelin. Campbell‖, in repeating Gmelin's experiment, threw out the intelligent suggestion that the purple colour might be due to the production of a sulphuret of nitrogen, which Gregory¶ had already remarked produced an amethystine colour when mixed with an alcoholic solution of potash. Smee**, in an examination of the action of nitric acid on the prussides, observes that ferridcyanide is produced, nitric oxide being evolved.

I am not aware of any further knowledge on this subject; and as it is far from being sufficiently extended, a new examination was desirable.

2. When dissolved ferrocyanide of potassium is digested with diluted nitric acid, a coffee-coloured liquid is produced, having the characters ascribed to it by Döbereiner and Gmelin. The addition of this acid solution to sulphide of potassium dissolved in water causes a precipitation of sulphur and the production of various colours, from a pink to a violet or blue shade. When the acid liquid is neutralized with potash, it

* As quoted by Gmelin, Handbuch, Band iv. s. 370.

† Schw. J. xxvi. p. 305.

‡ Ann. Pharm. Bd. xxviii. s. 57, and Memoirs of Chem. Soc. vol. i. p. 41.

§ Unpublished Letter.

‖ Handbuch, B. i. s. 167.

¶ Turner's Chemistry, p. 343.

** Phil. Mag. xvii. 194.

immediately produces the most intense purple coloration with a soluble sulphide*. The action of nitric acid on the pounded salt is similar, but much more violent than that experienced with the solution. Nitric oxide is at first evolved, but it soon ceases if the mixture be kept cool, and it is followed by the copious escape of cyanogen gas, accompanied by hydrocyanic acid, and a gas of peculiar pungency, apparently hydrated cyanic acid; more or less nitrogen and carbonic acid are also found in the escaping gases. The dark red solution remaining after the action, deposits, on cooling, abundance of nitrate of potash, and, under the most favourable circumstances, about 5 per cent. of a peculiar *white substance*, afterwards to be described. The red-coloured solution now precipitates protosalts of iron of a dark blue colour, or if it has been heated for a short time, or even stood in the cold for some days, of a dark green, and sometimes of a slate colour. A dark green precipitate is also produced on the addition of salts of copper. The same precipitates are obtained from the neutralized as from the acid solution. Such were the preliminary observations made on repeating DOBEREINER's experiment.

One important fact was observed in this preliminary trial, viz. that nitric oxide disappeared during the action, and in fact only occurred when the transformation was so violent as to escape control. This gas was therefore probably one important cause of the change, and it therefore became necessary to examine its action on the cyanides, as a more simple means of eliciting its mode of action.

3. The first obvious experiment was to ascertain whether cyanide of potassium charged with nitric oxide would produce prussides exerting the remarkable colouring action on the sulphides. Nitric oxide is in fact readily absorbed by cyanide of potassium, the solution becoming red-coloured and depositing a black substance resembling paracyanogen. This red-coloured solution did not of itself give any colour when mixed with a sulphide. It was now converted into a prusside by the addition of protosulphate of iron. The resulting prusside was now found to strike a magnificent purple colour with a soluble sulphide. The same coloration was obtained when a prusside was made from common cyanide of potassium added to a solution of protosulphate of iron, through which nitric oxide had been passed. It was obvious from these experiments that nitric oxide was one of the great causes of the change experienced by the prusside.

4. The action of nitric oxide on the prussides themselves was now examined. It was found that nitric oxide could be passed through a solution of ferrocyanide of potassium without producing any sensible change. But when the prusside was mixed with sufficient acid to take up its alkaline base, it was now found that nitric oxide was freely absorbed by this mixture when heated, though not in the cold; and that

* The intensity and beauty of this coloration render the nitroprussides the most sensible of all tests for the presence of the minutest trace of a soluble sulphide. The presence of quantities insensible to ordinary tests is at once strongly exhibited by the use of this colouring agent.

the resulting liquid exhibited the strong coloration with sulphides. Ferrocyanide of lead, or any other ferrocyanide, gave, when mixed with strong acids, a similar result. It was therefore obvious that the peculiar compound might be obtained from pure hydroferrocyanic acid. The latter acid was prepared from prusside of lead by sulphuretted hydrogen, the excess of the latter being removed by the addition of a little more lead salt. The filtered ferrocyanic acid was found to suffer no change when exposed to the action of nitric oxide in the cold; but when the solution was kept in a water-bath and the gas led through it, a change was observed. This, however, at first merely consisted in the transformation of ferrocyanic to ferridcyanic acid,—

$$4(Fe\,Cy_3+2H)+NO_2=2(Fe_2\,Cy_6+3H)+2HO+N.$$

Until this change was completed not the least coloration took place on mixing the acid liquid with a sulphide. When, however, the acid no longer gave prussian blue with perchloride of iron, it began to assume a red colour, continuing to evolve a gas, and it now exhibited, after neutralization, the peculiar coloration with sulphides. It now gave a blue precipitate with protosulphate of iron, like ordinary ferridcyanic acid. This blue precipitate became paler in colour as the gas continued to stream through the hot solution, until finally the addition of the iron salt gave a precipitate of a *clear salmon colour*. Here then was the acid* of the new compounds, and its salts were obtained by neutralization with the respective bases. This process was a great step in the inquiry, because it enabled the distinctive characters of the nitroprussides to be determined. At the same time it was not fitted to procure the salts in sufficiently large quantities for examination. By showing however what was to be looked for, it enabled a more complete examination to be made of the products of oxidation of the prussides by nitric acid, with a view to the separation of the nitroprussides from the ferridcyanides, with which they were obviously mixed.

5. It was observed that the oxidized prusside required a very small quantity of protosulphate of iron for its complete precipitation. One double equivalent of ferrocyanide of potassium ($Fe_2\,Cy_6+4K$) was oxidized with 3 equivs. of nitric acid diluted with its own volume of water. The dark red, almost black liquid, was diluted with water and treated with a known quantity of sulphate of iron dissolved in water. Prussian blue was formed, but it remained in *solution*, forming a dark blue soluble fluid, of great beauty and intensity. When the added sulphate of iron amounted to one equivalent, that is to one-fourth of the potassium originally in the prusside, the prussian blue became insoluble and was thrown on a filter and washed. It was obvious from this experiment that there must be a potassium salt in combination with the prussian blue, because the quantity of iron salt added was quite insufficient to unite with the iron and cyanogen of the radical. This idea was confirmed by

* On neutralizing this nitroprussic acid with carbonates, the resulting salts were found to be accompanied by a nitrate, although the nitric oxide had previously been passed through water in a washing-bottle.

finding that 2 equivs. of sulphate of copper were required to effect the precipitation, which 1 equiv. of sulphate of iron had effectually done. To separate the potassium salt present in the latter case, the precipitated prussian blue, after being washed with cold water, was mixed with water and boiled. The whole was now thrown on a filter, and a solution of a fine ruby-red colour passed through. This solution gave a salmon-coloured precipitate with a protosalt of iron. This precipitate does not readily occur in an acid liquid, and hence the addition of the iron salt to the original oxidized solution does not effect a complete precipitation, the filtrate from it being yellow from dissolved nitroprusside of iron. There being always some nitroprusside of iron along with the prussian blue, the simple treatment with hot water does not wholly economise the products, as it only separates the salt of potassium. The mixture may therefore be decomposed by caustic potash, which, added in sufficient quantity, forms peroxide of iron, and ferrocyanide instead of ferridcyanide,—

$$(Fe_2\,Cy_6+3K)+KO+2FeO=2(Fe\,Cy_3+2K)+Fe_2\,O_3.$$

The ferrocyanide may now be separated from the nitroprusside, either by precipitation by alcohol, or by the addition of nitrate of lead. These plans were not however so advantageous as the simple means of separation given above. That method was followed for some time until the examination of the nitroprussides threw some light on their properties and composition; it was then found that a process yielding a much larger product of the new compound, might be invented. The following study was therefore made of the products arising from the oxidation of the prussides by nitric acid. The knowledge thus obtained led, as was expected, to a very economical and simple means of obtaining the nitroprussides in large quantities.

6. As nitric oxide was one of the most important means of producing the conversion of prussides into nitroprussides, it was necessary to operate so as to prevent its escape. This was done by keeping the mixture of acid and prusside well-cooled at the first part of the action. Nitric oxide is almost always evolved at first, but it soon diminishes to nothing as the action proceeds. A copious evolution of gas takes place. The escaping gas burns with the characteristic purple flame of cyanogen. Led through protosulphate of iron, after the first violent action has ceased, no blackening is perceived, so that nitric oxide has ceased to be evolved. Led into caustic barytes, carbonate of barytes is precipitated, and the solution is found to contain cyanide of barium and cyanate of barytes. When the gas is collected over mercury and potash is thrown into the tube containing it, a portion of gas still remains unabsorbed and is easily recognized as nitrogen. When the escaping gas is led into water it is dissolved in considerable quantity, and the water now smells strongly of cyanogen and of a peculiar pungent gas, which appears to be hydrated cyanic acid. The gas treated with ammonia deposits azulmic acid, and the usual products of the transformation of cyanogen. The following process is found best adapted for the

preparation of the nitroprusside. Nitric acid of commerce is diluted with its own bulk of water, and the quantity of it necessary to neutralize 53·3 grs. of carbonate of soda (1 equiv.) is ascertained by the alkalimeter. This quantity denotes 1 equiv. of acid.

Ferrocyanide of potassium is now reduced to powder and is placed in a convenient vessel, and for every 422 grs. of the salt used (that is for 1 equiv. $Fe_2 Cy_6 4K + 6HO$) 5 equivs. of the acid are employed. This quantity of acid is found to produce an economical result, but it is very remarkable that one-fifth of the quantity, or 1 equiv., is sufficient to convert a large portion of the prusside into nitroprusside. This is the more remarkable, because there are four available equivalents of potassium, and it was to be expected that nitrate of potash would be produced. This however is not the case, 1 equiv. of nitric acid effecting oxidation to a considerable extent on a double equivalent of yellow prusside. The five equivalents of acid mentioned above are at once poured on the prusside, as the cooling effect of the whole reduces the violence of the action. The mixture assumes a milky appearance, but soon the salt dissolves with a brownish-red colour like coffee, the mixture of gases already described being freely evolved. When the solution is complete, it is found to contain ferridcyanide of potassium mixed with a nitroprusside and nitrate of potash. It is now removed into a bolt-head and digested in the water-bath. It continues to evolve gas, and after a time it no longer yields prussian blue with sulphate of iron, but forms a dark green or a slate-coloured precipitate, The solution is now removed from the water-bath and is allowed to cool, during which abundance of nitrate of potash crystallizes out, and always more or less of a peculiar white substance. The dark coffee-coloured mother-liquor is now neutralized with carbonate of soda or carbonate of potash, according as salts of sodium or potassium are desired. The neutralized solution shows the presence of iron existing as a base, for prussian blue is precipitated on the addition of a prusside. The neutral solution is now boiled, and it deposits generally a green precipitate, though occasionally one of a brown colour; and the filtrate is found to be of a dark ruby-red, containing only nitroprusside of the base employed and a nitrate. The latter is separated by crystallization in the manner pointed out under the respective salts. Nitroprusside of sodium being most easily prepared, is recommended as the product of the process here given.

Some practical difficulties may be mentioned so as to prevent disappointment in the preparation. A carbonate of and not the caustic alkali should be employed in the neutralization. When the latter is used, the solution of nitroprusside is apt to be mixed with ferrocyanide. When this takes place an addition of acid serves to remove the impurity, as some of the precipitated oxide of iron is dissolved, and forming prussian blue with the ferrocyanide, removes it from the solution. This impurity may also be removed by the addition of nitrate of lead, which precipitates the prusside but not the nitroprusside; or it may be taken away by the gradual addition of

sulphate of iron, which removes the ferrocyanide before precipitating the nitroprusside. When the quantity last added precipitates the solution of a salmon colour, the impurity has been removed*.

Red prusside (ferridcyanide) of potassium may be used in the preparation exactly as described for the yellow prusside.

7. The following experiments were made in order to ascertain approximatively how much nitroprusside was formed by the process now described. 105·5 grs. crystallized ferrocyanide of potassium were digested with 1½ equiv. of nitric acid. After digestion the liquid was neutralized with carbonate of soda and boiled, the resulting green precipitate being collected on a weighed filter. The filtrate was precipitated by a salt of copper, and the nitroprusside of copper was collected and weighed.

It was found by various trials that perfectly uniform results could not be obtained, the amount and even the composition of the precipitate† on boiling varying with the conditions of the preparation. The two following experiments may be taken as giving mean results:—

I. 105·5 grs. yellow prusside gave 8·275 green precipitate, yielding on incineration 7·95 grs. peroxide of iron; the filtrate gave 48·90 grs. nitroprusside of copper.

II. 105·5 grs. yellow prusside gave 8·32 grs. green precipitate, yielding by calculation 6·30 grs. peroxide of iron; the filtrate gave 46·12 grs. nitroprusside of copper.

Taking the mean of the two experiments, 105·5 grs., or one-fourth of the double equivalent of yellow prusside, yield 8·297 grs. green precipitate containing 4·984 grs. iron; the filtrate yields 47·51 grs. nitroprusside of copper. But before drawing deductions, it is necessary to know the composition of the green precipitate. It consists of a mixture of prussian blue, nitroprusside and peroxide of iron, this mixture not being constant. However, to take a special case as an example,—

22·26 grs., calcined and treated with nitrate of ammonia, gave 13·62 grs. peroxide of iron, or 42·83 per cent. of metallic iron.

9·49 grs. burned with oxide of copper, gave 4·13 grs. carbonic acid and 0·96 gr. water; the carbon is therefore 11·87 per cent., the water 10·11.

35·02 grs. treated by caustic potash, gave, when neutralized by acetic acid, a red

* It is perhaps needless to remark, that when the ruby-red solution free from prussides has been obtained by any of the processes above described, it may be used at once for the precipitation of the insoluble nitroprussides.

† The composition of the precipitates varies considerably. If on neutralizing the acid solution an excess of alkali be added, the addition of an acid gives a slaty precipitate, which consists mainly of oxide of iron mixed with prussian blue. Under somewhat similar conditions, I believe, though on this subject I am not certain, the precipitate on boiling, instead of being green, is brown, like oxide of iron. On washing and exposure to the air it becomes green.

In an experiment where this precipitate came, 105·5 grs. yellow prusside gave 5·83 grs. of a brown precipitate, and 50·66 grs. of nitroprusside of copper. In another experiment with a like quantity, 4·755 grs. of the brown precipitate were obtained.

filtrate, from which the ferrocyanide of potassium was precipitated by alcohol; the filtrate from this had all the properties of nitroprusside of potassium, and gave by precipitation with sulphate of copper 13·98 grs. nitroprusside of copper, equal to 13·24 grs. nitroprusside of iron, or 37·80 per cent.

The reactions in the preparation of the nitroprusside may now be approximatively explained.

By reference to the ascertained composition of the nitroprussides, it will be seen that the 47·51 grs. of the copper nitroprusside obtained from the 105·5 grs. of yellow prusside, are equal to 35·69 grs. anhydrous nitroprussic acid: this quantity contains 9·66 grs. of iron. Now 14 grs. iron were present in the yellow prusside used, so that about two-thirds of the iron have been converted into nitroprussic acid. The other third is in the green precipitate, which was found to contain 4·98 iron; if it had been one-third it should have been 4·66; of this quantity 1·19 is as nitroprusside of iron, and therefore 0·59 as nitroprussic acid. Hence we have out of the 14 grs. iron present in the ferrocyanide 10·25 grs. converted into nitroprussic acid, or very nearly three-fourths; the remaining one-fourth is partly as prussian blue and oxide of iron, and partly as the basic iron in the nitroprusside of iron.

The quantity of carbon or of cyanogen converted into nitroprusside has now to be examined. The 47·51 grs. copper nitroprusside contain 9·93 grs. of carbon, that in the nitroprusside of iron of the green precipitate would amount to 0·60, hence the carbon converted into nitroprussic acid is 10·53. There were 3 equivs. or 18 grs. of carbon in the yellow prusside, of which about $1\frac{3}{4}$ equiv. has been converted into nitroprusside; of the remaining $7\frac{1}{4}$ grs. carbon or 16·2 grs. cyanogen, about 0·38 gr. carbon or 0·823 gr. cyanogen remain in the green precipitate as a cyanide, the remainder escaping as a gas. It is true that the results here given only form a rude approximation, but they denote sufficiently the final, though not all the intermediate changes which occur; the ultimate action may be expressed by the following equation:—

$$8(Fe\,Cy_3+2K)+19(HO,\ NO_5)=16(KO,NO_5)+(Fe_5\,Cy_{12}\,3NO+5H)$$
$$+Fe\,Cy+Fe_2\,O_3+2H\,Cy+9Cy+12HO.$$

Thus 8 equivs. ferrocyanide of potassium lose their potash by 16 equivs. of nitric acid, and the hydroferrocyanic acid formed is oxidized at the expense of 3 equivs. nitric acid, the 3 equivs. of nitrous oxide thus formed entering into the constitution of nitroprussic acid, 12 equivs. of water being formed by the oxidation. Of the cyanogen, 12 equivs. remain in the nitroprussic acid, 2 equivs. escape as hydrocyanic acid, 9 equivs. as cyanogen, and 1 equiv. remains united with iron as a cyanide. This scheme would require 10·04 grs. of the iron experimented on to be converted into nitroprussic acid, and direct experiment gave 10·2 grs. We should indeed find 1·8 gr. cyanogen in the cyanide of iron*, whereas only 0·823 gr. cyanogen was found

* The empirical formula Fe Cy represents the actual proportion of iron and cyanogen in certain prussian blues, although the elements are not arranged according to this simple expression.

in this state; but when we consider the small quantity present and the variable nature of prussian blues, such a discordance is not fatal to the correctness of an explanation, which is only given as an approximation.

8. It has already been mentioned that carbonic acid was one of the products evolved as a gas. This acid scarcely appears at all when the quantity of nitric acid used is only 1 equiv. for every 4 equivs. of potassium in the prusside. On the contrary, it is a very marked product when 5 equivs. are employed. Precisely under the same circumstances that the carbonic acid is least in quantity, does the peculiar white substance, already referred to, augment, and when the carbonic acid is greatest, as when five equivalents of nitric acid are used, then scarcely any of the white substance is observed. The carbonic acid is therefore obviously a product of the oxidation of the white substance. Five per cent. of the white substance were obtained when one equivalent of nitric acid was used to oxidize an amount of yellow prusside containing 4 equivs. of potassium; to ensure this, the largest quantity obtained by experiment, the action of the acid on the prusside must be as subdued as possible. The white substance is found with the nitrate of potash, which has deposited from the oxidized liquid, and is separated from it by the solution of the latter in water. The white substance is scarcely at all soluble in cold water, and therefore may be collected and purified by repeated solutions in boiling water, in which it is only very sparingly soluble, and deposits itself, on cooling of the solution, as a white crystalline precipitate. It may also be sublimed without change between two watch-glasses. The following analyses of this white substance show its composition. Analyses I. II. were made upon a specimen purified by sublimation; III. IV. upon a specimen purified by solution.

I. 5·05 grs. gave 5·004 grs. carbonic acid and 2·094 grs. water.
II. 7·835 grs. gave 7·850 grs. carbonic acid and 3·236 grs. water.
III. 5·947 grs. gave 5·95 grs. carbonic acid and 2·46 grs. water.
IV. 6·992 grs. gave 6·95 grs. carbonic acid and 2·886 grs. water.

The nitrogen analyses were made by Will and Varrentrapp's plan, the portions used in analysis being in one case purified by sublimation and in the other by solution:

4·345 grs. gave 21·835 grs. platinum salt.
7·027 grs. gave 35·74 grs. platinum salt.

	Purified by sublimation.		Purified by solution.				Calculated.
Carbon	27·024	27·324	27·255	27·108	2	12	27·27
Nitrogen	31·583	31·583	31·961	31·961	1	14	31·81
Hydrogen ...	4·607	4·589	4·594	4·586	2	2	4·54
Oxygen	36·786	36·584	36·190	36·345	2	16	36·38
	100·000	100·000	100·000	100·000			100·00

The carbon is to the nitrogen as 2 : 1, or in the same proportion as cyanogen. In

fact the formula Cy+2HO correctly represents the composition, and the substance may be supposed to be formed by the union of cyanogen in its nascent state with 2 equivs. of water. When this white substance is treated with acids, it is converted into oxalic acid and ammonia. This fact, together with the analysis, proves it to be Oxamide*. Its occurrence in a process of oxidation is very surprising, and perhaps may throw some doubts on the theoretical composition ascribed to it, $2CO+NH_2$. There is little doubt that this substance is the same as that observed by Vauquelin† in a watery solution of cyanogen, which however was not analysed by him. The description which he gives applies closely to oxamide. Wöhler‡ also observed two substances in a watery solution of cyanogen, one of which may be this body. The appearance of carbonic acid is now explained, as it is obviously due to an oxidation of the oxalic acid produced by the transformation of the oxamide.

Section II.—*General remarks on the Nitroprussides.*

9. The nitroprussides are salts with characters so decided, that they cannot be confounded with any known series of compounds. They are generally highly coloured—the salts of potassium, ammonium, sodium, barium, calcium and lead being of a dark red or ruby colour; they are readily soluble in water, and communicate a dark red colour to the solution. Alcohol does not precipitate these salts from their solutions. The soluble nitroprussides crystallize readily, yielding large and well-defined crystals. The nitroprussides of copper, zinc, iron, nickel, cobalt and silver, are either wholly or nearly insoluble.

The following Table exhibits some of the characteristic reactions of a soluble nitroprusside:—

Reagents.	Behaviour of the nitroprusside.
Sulphides of the alkaline metals	Magnificent transitory purple colour.
Sulphuretted hydrogen	Produces prussian blue, a prusside and peculiar compound.
Neutral salts of lead	No change.
Basic salts of lead	White precipitate, after a time in strong solution.
Persalts of mercury	No change.
Proto- and persalts of tin	No change.
Salts of zinc	Light salmon-coloured precipitate.
Salts of copper	Light green precipitate.
Salts of nickel	Dirty white precipitate.
Salts of cobalt	Flesh-coloured precipitate.
Protosalts of iron	Salmon-coloured precipitate.
Persalts of iron	No change.
Caustic alkalies	Turn the red coloured solutions of an orange colour.

The beautiful colour immediately produced on the addition of a soluble sulphide, is a most marked character of the nitroprussides. This purple coloration is most in-

* In the descriptions of oxamide, it is usual to state that all acids convert it into oxalic acid and ammonia. It is however very readily soluble in concentrated sulphuric acid, from which it is again precipitated unchanged by the addition of water.

† Ann. de Chim. et de Phys. ix. 113; xxii. 132.

‡ Pogg. Ann. xv. 627.

tense, and enables the detection of the most minute quantity of either reagent. As a test for the presence of sulphides it is wonderfully useful, enabling minute quantities of them to be found in circumstances where the ordinary means of testing altogether fails to denote their presence. This purple coloration is however only transitory, the compound soon breaking up into various substances, among which, hydrocyanic acid, ammonia, nitrogen, oxide of iron, a ferrocyanide, a sulphocyanide and a hyponitrite may be recognized.

The soluble nitroprussides are decomposed when sulphuretted hydrogen is passed through them, oxide of iron, prussian blue, sulphur, a ferrocyanide, and a peculiar sulphur compound being among the products of decomposition.

The alkalies decompose the soluble nitroprussides when their solutions are mixed together and boiled. The products of the transformation in this case are oxide of iron, nitrogen, a ferrocyanide and a hyponitrite. An excess of ammonia, even in the cold, gradually decomposes the nitroprussides, nitrogen gas being evolved, and a peculiar uncrystallizable black compound remains as the result of the decomposition.

Sulphurous acid, the sulphites and hyposulphites exert no apparent action on the nitroprussides. They are however wholly decomposed by boiling them with concentrated sulphuric acid; during this decomposition, the peculiar purple colour due to sulphides is observed.

Chlorine does not produce any change when passed through solutions of the nitroprussides.

Prussian blue dissolves in an excess of some of the nitroprussides, forming a beautiful blue solution; when the prussian blue is in excess, it is able, under certain circumstances (see § 5), to remove the soluble nitroprusside from solution, but it again yields it up to boiling though not to cold water.

Some of the nitroprussides are very permanent and suffer no change in solution, either by exposure to the air or by the action of heat. Several, on the contrary, especially nitroprussic acid, the nitroprussides of barium, calcium and ammonium, decompose partially, either when their solutions are long kept, or speedily when they are boiled. Some of the products of decomposition are dissolved by the still undecomposed nitroprusside, and cannot be again separated from them by crystallization.

After this general idea of the habits of the nitroprussides, their individual salts and their transformations may be more easily studied.

Nitroprussic Acid.

10. This acid may be obtained in solution by decomposing nitroprusside of silver with an equivalent quantity of hydrochloric acid, or by precipitating nitroprusside of barium with an equivalent quantity of sulphuric acid. It may also be obtained, but in a less pure state, by precipitating nitroprusside of potassium dissolved in a small quantity of water, and diluted with several times its volume of alcohol, with an alco-

holic solution of tartaric acid, the quantity of the latter being just sufficient to form bitartrate of potash with the potassium; but as the acid dissolves some of the latter salt, this process does not yield a pure product.

A dark red-coloured solution, strongly acid, is obtained by these methods. Ether does not precipitate the acid as it does ferrocyanic acid. Soon however the solution begins to form hydrocyanic acid, and either to deposit oxide of iron or to hold iron in solution, which may be detected by a prusside. When this change has taken place, evaporation *in vacuo* over sulphuric acid yields crystals of the acid, which is however found to contain a small quantity of an impurity, probably of a cyanide of iron, which cannot be separated by crystallization, or any other of the numerous methods tried. The amount of this impurity is from 2 to 3 per cent. This crystalline acid belongs to the oblique system, and its crystals are described and measured in a further part of this paper, together with its analyses. It possesses all the properties of nitroprussic acid, and only differs by containing this small quantity of impurity. The perfectly pure acid in crystals has not been obtained, notwithstanding very many efforts to obtain this desirable result. *Vide* page 499.

Nitroprusside of Sodium.

11. This salt is the most readily procured, in a crystallized state, of all the nitroprussides; it may be obtained by decomposing the nitroprussides of copper or iron by means of soda, filtering from the oxides of these metals and evaporating the solution by a gentle heat. When prepared from the iron salt, it is apt to contain a little iron in excess.

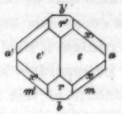
Nitroprusside of sodium is however most easily prepared in the following manner:—1 equiv. of yellow prusside of potassium is digested with 5 equivs. nitric acid, as described in page 481, until the solution precipitates salts of protoxide of iron of a slate colour. It is now neutralized with carbonate of soda, both solutions being employed cold. The neutralized liquid is now boiled, and the green precipitate is separated by filtration from the dark red-coloured solution. This is now evaporated down and again filtered from a brown precipitate which falls during evaporation. The nitrates of soda and potash are allowed to crystallize out.

The dark red solution is now evaporated on the sand-bath, and during evaporation prismatic crystals separate from the hot solution. These are removed, dissolved in water, and again crystallized by allowing the solution to cool. The reason of taking the crystals from the hot solution in the first instance is to obtain them uncontaminated with the nitrates, which are more soluble in hot water than this nitroprusside. By this process any quantity of the nitroprusside of sodium may be obtained in fine large ruby-coloured crystals.

Properties.—This salt crystallizes in fine ruby-coloured prisms, which have been measured by Prof. MILLER.

Symbols:—*a* 100, *b* 010, *e* 101, *r* 011, *m* 110, *x* 211. *x* is common to the zones *em*, *ra*. The angles between the normals to the faces are,—

	°	′
ba	90	0
ea	68	16
ee′	43	28
rb	62	26
rr′	55	8
ma	52	38·5
mb	37	21·5
mm′	74	43
rm	68	25
re	34	34
em	77	1
xm	49	24
en	27	37



Nitroprusside of sodium resembles very much in appearance the ordinary red prusside of potassium when the latter salt is crystallized from alkaline solutions*.

Nitroprusside of sodium is not at all deliquescent, but is very soluble in water, dissolving in 2½ times its weight of water† at 60°. It is still more soluble in hot water, but appears to have a point of less solubility at a particular temperature, for it may easily be crystallized by keeping its hot solution on the sand-bath, while it may not do so on cooling.

It is decomposed by mixing it with excess of alkali, and suffers the singular transformations with sulphurets of the alkaline metals which have been already alluded to. It undergoes no change in weight when heated to 212°, and therefore does not lose water in the water-bath.

The following analyses were made by heating the salt with sulphuric acid, and estimating the iron as peroxide, the sodium as sulphate of soda:—

Analyses I. and II. were made upon a salt obtained by acting on nitroprusside of iron with caustic soda. Analyses III. and IV. from a salt prepared from nitroprusside of copper. Analyses V. VI. and VII. from the process last described, by acting on yellow prusside of potassium with nitric acid and neutralizing with carbonate of soda; and analyses VIII. and IX. from another preparation in the same way.

I. 11·800 grs. gave 3·300 grs. peroxide of iron and 5·870 grs. sulphate of soda.
II. 10·300 grs. gave 2·930 grs. peroxide of iron and 5·000 grs. sulphate of soda.

* Red prussiate of potash crystallizes more easily and with much greater beauty from alkaline than from neutral or acid solutions; the reason being that the excess of alkali decomposes a small quantity of a green precipitate, which crystallizes along with it.

† 50·12 grs. saturated solution at 60° gave 14·46 salt; in another experiment 42·88 grs. solution gave 12·45 grs. salt, both being dried in water-bath.

III. 13·767 grs. gave 3·813 grs. peroxide of iron and 6·440 grs. sulphate of soda.
IV. 21·536 grs. gave 5·932 grs. peroxide of iron and 10·410 grs. sulphate of soda.
V. 19·610 grs. gave 5·470 grs. peroxide of iron and 9·890 grs. sulphate of soda.
VI. 13·545 grs. gave 3·740 grs. peroxide of iron and 6·450 grs. sulphate of soda.
VII. 15·740 grs. gave 4·420 grs. peroxide of iron.
VIII. 13·788 grs. gave 3·880 grs. peroxide of iron and 6·710 grs. sulphate of soda.
IX. 25·155 grs. gave 7·028 grs. peroxide of iron and 12·120 grs. sulphate of soda.

The combustions were made with chromate of lead.

I. 9·188 grs. gave 6·870 grs. carbonic acid and 1·300 gr. water.
II. 8·580 grs. gave 6·315 grs. carbonic acid and 1·224 gr. water.
III. 13·815 grs. gave 10·080 grs. carbonic acid and 1·780 gr. water.
IV. 8·765 grs. gave 6·570 grs. carbonic acid and 1·280 gr. water.
V. 12·010 grs. gave 8·790 grs. carbonic acid and 1·450 gr. water.
VI. 15·070 grs. gave 10·790 grs. carbonic acid and 1·820 gr. water.
VII. 9·000 grs. gave 6·580 grs. carbonic acid and 1·110 gr. water.
VIII. 8·645 grs. gave 6·340 grs. carbonic acid and 1·184 gr. water.
IX. 10·921 grs. gave 8·035 grs. carbonic acid and 1·309 gr. water.

The nitrogen in this salt was determined by DUMAS' quantitative method, an air-pump being used, so as to facilitate the expulsion of air from the apparatus.

I. 7·903 grs., by DUMAS' quantitative method, gave 117 CC. gas; thermometer 11°·1 C.; barometer 30·415 inches. Hence the nitrogen is 27·781 per cent.

II. 4·6 grs., also treated by DUMAS' method, gave 68 CC. gas; thermometer 45° FAHR.; barometer 30·742 inches. Per-centage of nitrogen 28·79.

	From Iron Salt.		From Copper Salt.		From Prusside of Potassium.				
Iron	19·576	19·912	19·387	19·281	19·525	19·320	19·56	19·69	19·59
Sodium	16·114	15·718	15·160	15·795	16·348	.....	15·88	15·90	15·76
Carbon	20·392	20·073	19·899	20·442	19·960	19·530	19·94	20·00	20·06
Hydrogen	1·572	1·585	1·437	1·622	1·340	1·340	1·37	1·52	1·33
Nitrogen, Oxygen	42·346	42·712	27·781, 16·336	42·860	28·790, 14·037	.....	43·25	42·89	43·26
	100·000	100·000	100·000	100·000	100·000		100·00	100·00	100·00

In order to estimate the water with more precision than can be done in an organic analysis, a portion of salt was heated in an F tube to which a chloride of calcium tube was attached; 9·52 grs. gave 1·20 gr. water, equal to 1·40 hydrogen per cent.

The above analyses correspond to the following calculated formula:—

			Calculation.
5	Iron	140	19·33
5	Sodium	116	16·02
24	Carbon	144	19·89
15	Nitrogen	210	29·00
10	Hydrogen	10	1·38
13	Oxygen	104	14·38
		724	100·00

It is obvious that if the analyses would authorise 25 equivs. of carbon instead of 24, a very much more simple formula might be given. The mean proportion of iron to carbon is 19·54 : 20·03, while the proportion, 5 equivs. : 25 equivs. or 1 : 5, would require 19·54 : 20·93 of carbon. Throughout all the salts, this less quantity of carbon refuses to enrol itself in the simple proportion of 1 : 5, and necessitates the use of the much more complex one of 5 : 24. The above formula may be expressed as $Fe_5\ Cy_{12}\ 3NO, 5Na + 10HO$.

Nitroprusside of Potassium.

12. This salt may be obtained in several ways.

1. By acting upon prusside of potassium with nitric acid, exactly as described under nitroprusside of sodium, but the neutralization of the acid is effected by carbonate of potash, instead of carbonate of soda as therein described. The nitrate of potash is crystallized out and the mother-liquor is put in the hot chamber to crystallize.

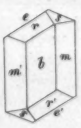
2. It may be prepared from the nitroprusside of iron, or better from the copper salt, by decomposing it with caustic potash, care being taken to keep the nitroprusside in excess.

Properties.—This salt, from its great solubility, is somewhat difficult to crystallize. It is apt to deposit in an amorphous form; but this may be avoided by a little practice, and fine large crystals may be obtained. These crystals belong to the oblique system, and have been measured by Prof. MILLER.

Symbols:—$b\,010$, $m\,110$, $s\,012$, $e\,\bar{1}01$, $r\,\bar{1}11$.

Angles between normals to the faces :—

	°	′
ab	30	0
rb	54	5
mb	49	46
sb	68	52
em	113	55
es	57	7
sm	69	3



The axis of the zone *mb*, makes an angle of 57° 56′ with that of the zone *rb*, and an angle of 71° 0′ with the axis of the zone *sb*.

This salt dissolves in its own weight of water at 60°; 60·06 grs. of a saturated solution of this salt evaporated in the water-bath left 30·40 grs. of the salt. It is not precipitated from its solution by alcohol. With caustic potash it unites and forms a salt which is described in a further part of the paper. Nascent hydrogen does not decompose it. Hydrogen, chlorine and sulphurous acid were passed through both cold and hot solutions of the salt without effecting any change. It is slightly deliquescent, and acquires a greenish shade when exposed to light; its solutions on long keeping deposit prussian blue and become partially decomposed.

The crystals of this salt are of a dark red colour.

The analysis was made by decomposing the salt by Nordhausen sulphuric acid. The following estimations give the amount of water lost in the water-bath:—

I. 14·865 grs. lost 1·765 grs., or 11·873 per cent.
II. 15·455 grs. lost 1·855 grs., or 12·002 per cent.
III. 12·430 grs. lost 1·480 grs., or 11·906 per cent.
IV. 20·155 grs. lost 2·245 grs., or 11·138 per cent.

Mean . . 11·730

The inorganic analyses yielded the following results:—

I. 23·905 grs. gave 6·479 grs. peroxide of iron and 13·837 grs. sulphate of potash.
II. 20·145 grs. gave 5·525 grs. peroxide of iron and 12·105 grs. sulphate of potash.
III. 13·015 grs. gave 3·550 grs. peroxide of iron and 7·660 grs. sulphate of potash.
IV. 12·945 grs. gave 3·536 grs. peroxide of iron and 7·600 grs. sulphate of potash.
V. 17·195 grs. gave 4·832 grs. peroxide of iron.

The organic analyses were made with chromate of lead.

I. 7·475 grs. gave 0·448 gr. water and 5·403 grs. carbonic acid.
II. 7·122 grs. gave 0·425 gr. water and 5·105 grs. carbonic acid.

	I.	II.	III.	IV.	V.	Mean.
Iron . .	18·972	19·198	19·093	19·120	18·901	19·056
Potassium	25·947	26·934	26·385	26·388	....	26·413
Carbon .	19·712	19·548	....	....	....	19·630
Hydrogen	0·665	0·663	....	....	....	0·664
Nitrogen } Oxygen . }	34·704	33·657	....	....	....	34·237
	100·000	100·000				100·000

These results may be expressed by the following calculation:—

			Calculated.	Mean.
5	Iron	140	18·92	19·056
5	Potassium . .	195	26·35	26·413
24	Carbon . . .	144	19·46	19·630
3	Hydrogen . .	3	0·40	0·664
15	Nitrogen . . .	210	28·38	34·237
6	Oxygen . . .	48	6·49	
		740	100·00	100·000

According to this calculation the formula of the salt dried at 212° is $Fe_5\ Cy_{12}\ 3NO, 5K + 3HO$; the salt loses in the water-bath 11·73 per cent. of water; had it lost 12·7 per cent. this would have corresponded to 12 equivs.; 11 equivs. would yield a loss of 10·6 per cent.

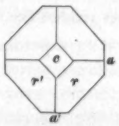
Nitroprusside of Barium.

13. This salt is obtained by decomposing nitroprusside of copper by caustic barytes, avoiding an excess of the latter. On filtration a dark red-coloured solution passes through. When evaporated under the air-pump, it forms fine large pyramidal crystals. The following measurements have been made by Prof. Miller of Cambridge:—

Symbols:—*a* 100, *c* 001, *r* 111.

Angles between normals to the faces:—

	°	′
ac	90	0
aa′	90	0
rc	44	35
rr′	59	30
ra	60	15



This salt, out of a strong solution, also frequently crystallizes in flattened prisms; no doubt as a different hydrate.

Nitroprusside of barium is of a dark red colour, is easily soluble in water, and is not deliquescent. It deposits a brown precipitate on boiling, resembling oxide of iron, but which, in the specimen examined, also contained barytes. The salt, after it has experienced this change, crystallizes in the same form, but with impurities which cannot be separated by filtration or crystallization. Analyses of this altered salt are given, page 504.

The salt crystallized in the air-pump lost water in water-bath.

20·415 grs. lost at 212° 3·110 grs. water = 15·233 per cent.
24·455 grs. lost at 210° 3·648 grs. water = 14·917 per cent.

The analyses were made by acting upon the salt by sulphuric acid in the usual way.

I. 20·791 grs. gave 12·173 grs. sulphate of barytes and 4·180 grs. oxide of iron.
II. 17·240 grs. gave 10·198 grs. sulphate of barytes and 3·480 grs. oxide of iron.

The combustions were made with chromate of lead.

I. 8·539 grs. gave 1·208 gr. water and 4·665 grs. carbonic acid.
II. 10·068 grs. gave 1·132 gr. water and 5·580 grs. carbonic acid.

	I.	II.			Calculated.
Iron . .	14·073	14·129	5	140	14·05
Barium .	34·446	34·791	5	343	34·43
Carbon .	14·899	15·075	24	144	14·45
Hydrogen	1·571	1·249	15	15	1·50
Nitrogen	35·011	34·756	15	210	35·57
Oxygen			18	144	
	100·00	100·00		996	100·00

In the above analysis the proportion of carbon to the iron is higher than obtained with the other salts, but the error is usually on this side when chromate of lead, as in this instance, is used in the combustion. It will also be seen in a further part of the paper, that a carbonaceous impurity, probably an attached cyanide, not separable by crystallization, but removed when it is converted into a silver salt, is produced when a solution of this salt is kept for some time, and it is possible that a small portion may be present in the salt analysed. If we could be assured of the absence of all impurity, which it will be afterwards seen that it is difficult to believe from the variable composition of this salt, it is obvious that the above analyses might be much more simply expressed by the following calculation:—

		Calculated.
2 Iron	56	14·03
2 Barium . . .	137	34·33
10 Carbon . . .	60	15·03
6 Hydrogen . .	6	1·50
6 Nitrogen . .	84	35·11
7 Oxygen . . .	56	
	399	100·00

On the first formula the dried salt would be $Fe_5\,Cy_{12}\,3NO, 5Ba+15HO$, on the second $Fe_2\,Cy_5\,NO, Ba_2+6HO$. The water lost in the water-bath would in the first case correspond to 20 equivs., in the latter case to 8 equivs.

Nitroprusside of Silver.

14. This salt may be prepared by adding nitrate of silver to any of the soluble nitroprussides.

The colour of the salt varies according to its state of preparation, from a fleshy white to a pale buff. When dry it has a flesh colour. It is insoluble in water, alcohol and nitric acid. Hydrochloric acid decomposes it with the formation of nitroprussic acid and chloride of silver. The caustic alkalies decompose it, as they do the soluble nitroprussides generally: ammonia dissolves nitroprusside of silver, but it soon deposits white crystals, which are apt to be contaminated by oxide of iron. These white shining crystals are a compound of the salt with ammonia, and are quickly decomposed, even by water alone, but very readily by water acidulated with nitric acid. Ammonia is now found in solution and nitroprusside of silver remains. If ammonia and nitroprusside of silver be boiled together, a total decomposition takes place.

The salt was decomposed by sulphuric acid, the silver estimated as a chloride and the iron as peroxide. Each salt analysed was prepared at different times.

I. 14·788 grs. gave 2·749 grs. oxide of iron and 9·925 grs. chloride of silver.
II. 22·838 grs. gave 4·220 grs. oxide of iron and 15·180 grs. chloride of silver.
III. 16·675 grs. gave 3·115 grs. oxide of iron and 11·09 grs. chloride of silver.
IV. 26·545 grs. gave 4·970 grs. oxide of iron and 17·78 grs. chloride of silver.

The combustions were made in the usual way.

I. 8·350 grs. gave 0·252 gr. water and 4·045 grs. carbonic acid.
II. 8·385 grs. gave 0·234 gr. water and 4·150 grs. carbonic acid.
III. 7·900 grs. gave 0·183 gr. water and 3·820 grs. carbonic acid.
IV. 9·415 grs. gave 0·120 gr. water and 4·577 grs. carbonic acid.

As this salt was well calculated to give correct knowledge with regard to the composition of the nitroprussides generally, the nitrogen was carefully determined by the three best processes, viz. those of Dumas, Liebig and Bunsen.

I. Quantitative estimation of nitrogen:—

6·808 grs. salt gave 69 C. C. nitrogen gas,

the thermometer being 7°·7 C. and the barometer 30·094 inches. This makes the nitrogen 19·299 per cent.

II. Liebig's method:—

Tubes.	Vol. mixed gases.	Vol. after absorption.	Vol. of carbonic acid.
1.	21·0	8·15	12·85
2.	18·4	7·3	11·1
3.	24·0	9·25	14·75
4.	20·15	7·45	12·70
5.	13·3	5·35	7·95
6.	26·20	9·2	17·0
	123·05	46·70	76·35

Hence the proportion of nitrogen to carbonic acid is as 1 : 1·63. This, calculated on 13·288, the mean quantity of carbon, gives 19·02 per cent.

Bunsen's method:—

	Obs. vol.	Barom. inches.	Therm.	Col. merc.
Vol. of mixed gases (moist) .	110·8	757·7	16°·2 C.	217·0
Vol. after absorption (dry) .	46·2	761·9	16·2	218·0

Corrected vol. of mixed gases . . .	66·801
Corrected vol. of nitrogen	25·800
Vol. of carbonic acid	41·001

Hence the proportion of nitrogen to carbonic acid is as 1 : 1·589, which calculated on 13·288 carbon, gives 19·512 per cent.

	I.	II.	III.	IV.	Mean.			Calculated.
Iron . . .	13·012	12·934	13·076	13·106	13·032	5	140	13·011
Silver . .	50·546	50·000	49·925	50·040	50·128	5	540	50·185
Carbon . .	18·211	13·508	13·177	13·257	13·288	24	144	13·382
Hydrogen .	0·330	0·310	0·250	0·140	0·257	2	2	0·185
Nitrogen .	19·299	19·020	19·512	23·457	19·277	15	210	19·516
Oxygen .	3·602	4·228	4·060		4·118	5	40	3·721
	100·000	100·000	100·000	100·000	100·000		1076	100·000

With a quantity of hydrogen so small as that in the above analysis, it is difficult to obtain accordant results in an organic analysis. A portion of well-dried salt was therefore heated in an F tube, to which a tube filled with chloride of calcium was attached.

5·375 grs. gave 0·085 gr. water, equal to 0·175 H. per cent.
4·000 grs. gave 0·065 gr. water, equal to 0·180 H. per cent.

It is therefore quite certain that the silver salt dried at 212° still retains 1½ per cent. of water. It loses however this water at a higher heat and becomes anhydrous. The formula of the silver salt is therefore $Fe_5\,Cy_{12}\,3NO,\,Ag_5+2HO$.

Nitroprusside of Copper.

15. This salt is obtained by adding a solution of a copper salt to that of a nitroprusside. As it is insoluble in cold water, and almost entirely so in hot, it may be washed to any extent.

It is of a pale green colour, which changes to slate colour when exposed to light in the moist state. It is quite insoluble in alcohol. It is decomposed by the caustic alkalies, first passing into a dark brown basic nitroprusside, and then into oxide of copper and a soluble nitroprusside.

Nitroprusside of copper, dried in the hot chamber at about 100° Fahr., still lost weight in the water-bath.

45·60 grs. lost in water-bath 4·525, or 9·922 per cent.
25·12 grs. lost in water-bath 2·870, or 11·425 per cent.

The analysis of the dried salt was made by decomposing it with sulphuric acid, and estimating the two metals as oxides, after separating them in the usual way by sulphuretted hydrogen.

I. 22·24 grs. gave 6·325 grs. oxide of copper and 6·515 grs. peroxide of iron.
II. 21·00 grs. gave 6·018 grs. oxide of copper and 6·120 grs. peroxide of iron.

The combustions were made with chromate of lead and with oxide of copper.

I. 8·100 grs. gave 0·230 gr. water and 6·343 grs. carbonic acid.
II. 7·977 grs. gave 0·240 gr. water and 6·217 grs. carbonic acid.
III. 9·887 grs. gave 0·330 gr. water and 7·694 grs. carbonic acid.
IV. 11·507 grs. gave 0·320 gr. water and 8·936 grs. carbonic acid.

The nitrogen was determined in three different ways.

I. Dumas' quantitative method:—

6·226 grs. gave 98 CC. nitrogen gas. Barom. 30·105 inches. Therm. 8°·8 C.

II. Bunsen's method:—

	Vol.	Barom. inches.	Therm. °	Col. merc.
Vol. mixed gases (moist) .	246·3	29·988	15·6	219·7
Vol. after absorption (dry) .	121·1	30·069	15·4	348·0

Corrected vol. of mixed gases . . .	123·180
Corrected vol. of nitrogen	47·491
Corrected vol. of carbonic acid . .	75·689

Hence the proportion of nitrogen to carbonic acid is 1 : 1·593, which calculated on the mean quantity of carbon (21·25), yields 31·12 per cent. nitrogen.

III. Liebig's method:—

Tubes.	Vol. mixed gases.	Vol. after absorption.	Vol. of carbonic acid.
1.	21·2	8·0	13·2
2.	22·4	9·1	13·3
3.	26·0	10·4	15·6
4.	21·7	8·2	13·5
5.	28·3	10·6	17·7
6.	17·9	6·7	11·2
7.	22·2	8·2	14·0
8.	19·8	7·5	12·3
9.	20·0	8·0	12·0
10.	22·7	9·0	13·7
11.	28·0	10·8	17·2
12.	19·2	7·3	11·9
13.	14·6	5·4	9·2
	284·0	109·2	174·8

Hence the proportion of nitrogen to carbonic acid is 1 : 1·60.

	I.	II.	III.	IV.	Mean.			Calculated.
Iron . . .	20·506	20·400	. . . .	. . . .	20·453	5	140	20·43
Copper . .	22·708	22·880	. . . .	. . . .	22·794	5	158	23·06
Carbon . .	21·351	21·255	21·222	21·179	21·251	24	144	21·02
Hydrogen .	0·315	0·309	0·371	0·308	0·325	1	1	0·14
Nitrogen .	29·856	31·120	30·980	. . . .	30·652	15	210	30·65
Oxygen . .	5·264	4·036	. . . .	. . . .	4·515	4	32	4·70
	100·000	100·000			100·000		685	100·00

The formula of the copper salt is therefore $Fe_5\,Cy_{12}\,3NO,\,Cu_5+HO$.

Nitroprusside of Iron.

16. This salt is obtained by adding sulphate of the protoxide of iron to a soluble nitroprusside. When the solutions are dilute the precipitate does not at first appear; as however it is very sparingly soluble, it may be purified by washing either with hot or cold water.

This salt is a salmon-coloured precipitate, nearly though not absolutely insoluble in water; it is more soluble in water rendered acid by nitric acid. It is decomposed by caustic alkalies, with the precipitation of oxide of iron and the formation of a

soluble nitroprusside. Before however being completely decomposed, a dark-coloured basic nitroprusside of iron is produced.

A salt dried in the hot chamber, at a temperature about 90° Fahr., still lost water when exposed in the water-bath :—

14·162 grs. lost at 212° 2·890 grs., or 20·406 per cent.
10·893 grs. lost at 212° 2·320 grs., or 21·298 per cent.
17·500 grs. lost at 212° 3·545 grs., or 20·257 per cent.

In the two first analyses given below, the iron was determined by decomposing the salt by sulphuric acid, oxidizing with nitric acid and precipitation by ammonia. The third estimation was by calcination, a little nitrate of ammonia being used to effect complete oxidation.

I. 18·075 grs. gave 9·917 grs. peroxide of iron.
II. 30·935 grs. gave 16·900 grs. peroxide of iron.
III. 9·220 grs. gave 4·995 grs. peroxide of iron.

The combustions were performed with chromate of lead.

I. 7·218 grs. gave 0·717 gr. water and 5·255 grs. carbonic acid.
II. 7·347 grs. gave 0·810 gr. water and 5·360 grs. carbonic acid.
III. 6·360 grs. gave 0·693 gr. water and 4·695 grs. carbonic acid.

The nitrogen was determined by Dumas' quantitative method.

5·427 grs. gave 86 CC. nitrogen gas, the thermometer being 48°·7 Fahr. (9·4 Cent.) and the barometer 29·285 inches.

	I.	II.	III.	Mean.			Calculated.
Iron	38·406	38·241	37·922	38·189	10	280	38·35
Carbon . . .	19·855	19·896	20·136	19·962	24	144	19·72
Nitrogen . .	29·285	29·285	29·285	29·285	15	210	28·76
Hydrogen .	1·103	1·224	1·210	1·179	8	8	1·09
Oxygen . .	11·351	11·354	11·447	11·385	11	88	12·08
	100·000	100·000	100·000	100·000		730	100·00

The formula of the iron salt, dried at 212°, would therefore be

$$Fe_5\ Cy_{12}\ 3NO\ Fe_5 + 8HO.$$

Nitroprusside of Zinc.

17. This salt is prepared by precipitating one of the soluble salts of zinc by a nitroprusside. It is a salmon-coloured precipitate, of a more fleshy colour than the iron salt. When formed slowly, as when muriatic acid and zinc are made to act on nitroprusside of soda, it is of a deep orange colour.

Nitroprusside of zinc is very slightly soluble in cold water, rather more so in hot water. In its behaviour to reagents it acts exactly like the iron nitroprusside. It was analysed by decomposing it with sulphuric acid, separating the iron by succinate of ammonia and determining the zinc as a carbonate.

I. 24·14 grs. gave 6·92 grs. peroxide of iron and 6·70 grs. oxide zinc.
9·43 grs. gave 7·10 grs. carbonic acid and 0·335 gr. water.

				Calculated.
Iron	20·07	5	140	20·11
Zinc	22·26	5	160	22·98
Carbon	20·53	24	144	20·69
Hydrogen . . .	0·39	2	2	0·28
Nitrogen } . . .	36·75	15	210 }	35·94
Oxygen }		5	40 }	
	100·00		696	100·00

This analysis would lead to the formula $Fe_5\,Cy_{12}\,3NO\,Zn_5+2HO$.

SECTION III.—*Changes experienced by certain Nitroprussides when their solutions are heated or kept.*

18. Several of the nitroprussides, especially nitroprussic acid, nitroprussides of ammonium, barium and calcium, deposit either prussian blue or oxide of iron when their solutions are heated or are kept for some time. The residual liquid, after evaporation, yields crystals of the same shape and exactly of the same properties as before. Analysis however shows that some change has resulted in their composition, for the iron or electro-negative metal is now in greater than atomic proportion to the electro-positive metal. The proportion of carbon is also somewhat different. Still the difference in composition is not very considerable, although decidedly marked; it is not however sufficient to cause any obvious alteration in their general properties. In fact, there is an attached impurity, probably a cyanide of iron, which cannot now be removed by crystallization, precipitation, digestion with nitric acid, or any of the ordinary means of purification. This impurity, if it be one, remains so obstinately attached that all methods of purification have quite failed to remove it. This circumstance, before it was understood, had thrown the greatest difficulties in the way of the inquiry, and protracted it to a most tedious length by preventing the attainment of accordant results. It is to prevent the like inconvenience to those who repeat these experiments that this section of the paper is specially devoted. Attention has previously been drawn to the fact, that the nitroprussides form chemical compounds with the cyanides of iron. This seems to be a case of the same kind, but of more ultimate union. The impurity or chemically attached cyanide in this case appears to be $Fe\,Cy_2$, or perhaps $Fe\,Cy+H\,Cy$, judging from analysis only, for its separation has not been accomplished. The proportion in which it is present is very small, generally only $2(Fe\,Cy_2)$ to 7 equivs. of a nitroprusside, or if it be a chemical compound, $7(Fe_5\,Cy_{12}\,3NO+5R)+Fe_2\,Cy_4$. Still as the crystalline form and all the properties of the nitroprussides remain unchanged, we can scarcely view its presence in any other light than as an impurity. Several of the nitroprussides, viz. nitroprussic

acid and the nitroprussides of ammonium and calcium, have not yet been obtained free from this impurity, and are therefore described in this section.

Nitroprussic Acid.

19. The mode of preparation of this acid has been already described at page 486. It is however most readily prepared from nitroprusside of silver by adding to it as much hydrochloric acid as suffices to form chloride of silver with the silver in the salt. The dark red solution thus obtained soon evolves hydrocyanic acid, even in the cold, and after a time prusside of potassium indicates the presence of iron in solution. If the solution be heated, it deposits abundance of a brown precipitate resembling oxide of iron. When the latter is separated by filtration, and the solution is evaporated *in vacuo* over sulphuric acid, crystals are formed and may be separated; they must be dried over sulphuric acid, as they are exceedingly deliquescent. These crystals belong to the oblique system, but on account of their excessive tendency to deliquesce, it is difficult to measure their angles with accordant results. The angles between normals to the only faces which gave results to be depended on, are stated by Prof. MILLER to be as follows:—

	°	′
ec	36	57
e′c′	36	57
ee′	106	6

It will be seen that the equality of the angles *ec* and *e′c′* is a tolerably certain indication that the crystals belong to the oblique system.

The acid made by the action of hydrochloric acid on nitroprusside of silver, and evaporated over sulphuric acid in the cold, crystallized (light being excluded) without the deposition of oxide of iron, but the smell of hydrocyanic acid, accompanied by a peculiar pungent smell, was strongly perceptible. Analysis shows that these crystals are the same as those obtained from a boiled solution.

Properties of the Crystallized Acid.—The crystallized acid is of a dark red colour, and has a very acid reaction, the crystals being generally flattened and of tolerable size. They are quite as deliquescent as chloride of calcium. They dissolve to a large extent in water, and are also soluble in alcohol and in ether. They may be dried in the water-bath without change, but their aqueous solution cannot be boiled without decomposition.

The following analyses were made on crystals obtained from a boiled solution, and were dried at 212°. The acid was that made by the action of hydrochloric acid on the silver salt. Nos. I. II. and III. were preparations made at distinct times.

The iron was determined by calcination and by treating the residual oxide with nitrate of ammonia.

I. 2·345 grs. gave 0·800 gr. peroxide of iron.
II. 3·915 grs. gave 1·325 gr. peroxide of iron.
III. 3·580 grs. gave 1·220 gr. peroxide of iron.

The combustions were made in the usual way.

I. 7·720 grs. gave 7·005 grs. carbonic acid and 1·175 gr. water.
II. 10·810 grs. gave 9·880 grs. carbonic acid and 1·665 gr. water.
III. 4·385 grs. gave 3·980 grs. carbonic acid and 0·700 gr. water.

An estimation of nitrogen by BUNSEN's method gave the following result:—

	Obs. vol.	Barom. inches.	Therm.	Col. Merc.
Vol. of mixed gases (moist) . .	89·5	29·994	7°·0 C.	152·7
Vol. after absorption (dry) . .	37·4	30·015	9·2 C.	205·2

Corrected vol. of mixed gases . . .	52·995
After absorption of carbonic acid . .	20·570
Nitrogen	32·425

Hence the proportion of nitrogen to carbonic acid is 1 : 1·576.

	I.	II.	III.	Mean.			Calculated.
Iron	23·88	23·69	23·85	23·80	5	140	24·26
Carbon . . .	24·74	24·92	24·75	24·80	24	144	24·95
Hydrogen . .	1·69	1·71	1·77	1·72	11	11	1·90
Nitrogen . . .	36·73	36·73	36·73	36·73	15	210	36·39
Oxygen . . .	12·96	12·95	12·90	12·95	9	72	12·50
	100·00	100·00	100·00	100·00		577	100·00

The calculated result, especially as regards the hydrogen, is not sufficiently close to be the true expression of the analysis, but it is here given to show how far the acid differs from pure nitroprussic acid. It is indeed probable that the acid dried at 212° only contains 10 equivs. of water.

The acid is so remarkably deliquescent that it is very difficult to ascertain how much the crystals lose in the water-bath. The following analysis of the salt dried *in vacuo* over sulphuric acid shows a higher state of hydration. The sample analysed had never been heated, even in solution, so that it evaporated without the deposition of oxide of iron. Still the oxide was detected in the mother-liquor by ferrocyanide of potassium.

I. 3·225 grs. gave 1·010 gr. peroxide of iron.
II. 3·235 grs. gave 1·020 gr. peroxide of iron.
I. 5·830 grs. gave 5·020 grs. carbonic acid and 1·09 gr. water.
II. 8·225 grs. gave 7·060 grs. carbonic acid and 1·51 gr. water.

	I.	II.	Mean.
Iron	21·92	22·07	21·99
Carbon	23·48	23·32	23·40
Hydrogen . . .	2·07	2·03	2·05
Nitrogen . . . } Oxygen . . . }	52·53	52·58	52·56
	100·00	100·00	100·00

A silver salt made from the well-crystallized acid showed that the iron was in excess, and that the carbon was in the usual proportion (see p. 506). The analyses of these silver salts are given further on, in order to avoid repetition. The discussion as to the constitution of the acid is also deferred to that place.

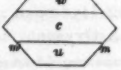
Nitroprusside of Ammonium.

20. When ammonia is added to an excess of nitroprusside of iron the latter is decomposed, oxide of iron being precipitated, but during the action nitrogen gas is evolved. If the red-coloured solution caused by filtration be evaporated in the air-pump, a difficultly crystallizable salt is obtained, which very readily decomposes, turning blue in the water-bath, and even when dried over sulphuric acid *in vacuo*. This salt is probably the true nitroprusside of ammonium, but it has not been obtained pure for analysis. If a solution of this salt be heated, prussian blue is deposited, and the filtered dark-red liquid, being evaporated by a gentle heat, now crystallizes in a warm place very readily, and in fine large red crystals, which are so dark as to be almost of a black colour. These have been measured by Prof. MILLER; they are prismatic, but the angles given are only approximative, the faces of the crystal examined being imperfect.

Symbols:—*c* 001, *m* 110, *u* 011.

Angles between normals to the faces:—

	°	′
mc	90	0
mm′	88	4
uc	55	3
uu′	110	6



They are twin crystals, the twin faces being *m*.

This salt is very soluble in water, from which it is not precipitated by alcohol. It is very slightly deliquescent. The salt dried in air loses water in the water-bath.

18·648 grs. lost at 212° 2·928 grs., or 15·701 per cent.
10·915 grs. lost at 212° 1·800 gr., or 16·491 per cent.
11·502 grs. lost at 212° 1·948 gr., or 16·936 per cent.
45·400 grs. lost at 212° 6·850 grs., or 15·088 per cent.

16·054

The iron was determined by calcination.

I. 10·905 grs. gave 3·455 grs. peroxide of iron.
II. 12·954 grs. gave 4·070 grs. peroxide of iron.

The combustions made with chromate of lead gave the following results:—

I. 9·822 grs. gave 2·903 grs. water and 8·251 grs. carbonic acid.
II. 12·765 grs. gave 3·682 grs. water and 10·494 grs. carbonic acid.
III. 7·215 grs. gave 2·010 grs. water and 6·020 grs. carbonic acid.

The nitrogen was determined by DUMAS' quantitative method.

I. 4·494 grs. salt gave 112 C.C. gas, the therm. being 47°½ Fahr., barom. 29·844 in.
II. 3·372 grs. salt gave 83 C.C. gas, the therm. being 50° Fahr., barom. 29·550 in.

This, calculated on 22·7 per cent. carbon, gives 43·619 per cent. nitrogen.

Again, 8·747 grs. salt distilled with a weak solution of soda, gave a distillate which, collected in hydrochloric acid, yielded 15·021 grs. platinum salt.

	I.	II.	III.	Mean.
Iron	22·177	21·993	....	22·085
Carbon . . .	22·901	22·420	22·755	22·692
Hydrogen . .	3·283	3·204	3·095	3·194
Nitrogen . . .	46·894	45·076	....	45·985
Oxygen . . .	4·745	7·307	....	6·044
	100·000	100·000		100·000

The ammonium per cent. from the amount of platinum salt is 13·872.

It is obvious that there is little hydrogen as water, for the greatest part is required to make up the ammonium (13·872 per cent. requires 3·08 hydrogen). Reserving, as in the other cases, the discussion as to the cause of difference between this salt and the pure nitroprusside, it will be convenient to give the calculation for nitroprusside of ammonium, of which the formula would be $Fe_5 Cy_{12} 3NO, 5NH_4 + 2HO$.

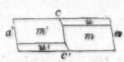
5	Iron	140	22·36
24	Carbon	144	23·00
20	Nitrogen	280	44·72
22	Hydrogen	22	3·51
5	Oxygen	40	6·41
		626	100·00

The hydrogen, but not the other constituents, would agree better with the above formula minus 2 equivs. of water; the hydrogen by the latter would be 3·28 per cent.

Nitroprusside of Calcium.

21. To prepare this salt, nitroprusside of iron or of copper is decomposed by milk of lime, the nitroprusside being kept in decided excess. A dark red solution is obtained, which on evaporation, even at a gentle heat, deposits prussian blue. When sufficiently concentrated the solution yields crystals of a dark red colour, and of considerable lustre. The crystals belong to the oblique system. They have been approximatively measured by Prof. Miller.

Symbols:—*a* 100, *c* 001, *m* 110; there are besides one or two faces in the zone *c m c'*, the symbols of which have not been found.



Cleavage *a* very perfect.

Angles between normals to faces approximately:—

	°	′
ac	82	0
ma	70	0
mm'	40	0

The values of *cu* were extremely discordant. In the best crystals, the angle between normals to *cu* was found to be 71° 41′.

Nitroprusside of calcium is very soluble in water, and in its behaviour to reagents is exactly the same as the soluble nitroprussides already described. By the mean of two experiments the crystallized salt lost 17·85 per cent. of water in the water-bath at 212°.

The salt was analysed by fusion with nitrate of ammonia, the iron and lime being determined in the usual way.

13·29 grs. gave 4·004 grs. peroxide of iron and 4·698 grs. carbonate of lime.

8·33 grs. burned with chromate of lead gave 6·56 grs. carbonic acid and 0·82 water.

				Calculated.
Iron	21·09	5	140	21·11
Calcium	14·14	5	100	15·08
Carbon	21·47	24	144	21·71
Hydrogen	1·09	5	5	0·75
Nitrogen, Oxygen	42·21	210, 8	210, 64	41·35
	100·00		663	100·00

It will be seen that this salt belongs to the class which has dissolved some of the cyanide of iron resulting from its partial decomposition, and that therefore the electro-positive metal is in too small quantity. Allowing for this impurity, which cannot be removed, it is probable that the pure nitroprusside of calcium has the formula $Fe_5\,Cy_{12}\,3NO, Ca_5+5HO$. The loss of water in the water-bath corresponds to 15 equivs., which ought to have given the loss as 17 per cent. In one experiment it lost 17·44 per cent., in another 18·26. We may conclude that the formula of the crystallized salt is $Fe_5\,Cy_{12}\,3NO, Ca_5+20HO$.

Altered Nitroprusside of Barium.

22. When a solution of nitroprusside of barium is boiled, it deposits a brown precipitate containing both iron and barium*. The solution now crystallizes either in pyramidal or in prismatic crystals, that is, in the first state when crystallized slowly, in the second when deposited quickly from a hot solution. It is now found that the salt is inconstant in composition, different preparations giving very discordant results. The salt is however peculiarly difficult to dry, having to be kept in the water-bath for days before it ceases to lose weight; it abstracts water when dried most speedily from the atmosphere.

It is found that the carbon is increased in a marked degree. The following two specimens were made at different times and analysed. Analyses I. and II. were made

* The barytes used in decomposing the nitroprusside of copper was that made by boiling peroxide of manganese with sulphuret of barium. It always contains a little hyposulphite, and the brown precipitate was found to contain sulphate of barytes.

on the same specimen, but crystallized over again for analysis II. No. III. is on a totally different specimen.

I. 14·40 grs. gave 8·62 grs. sulphate of barytes and 3·12 grs. oxide of iron.
II. 15·90 grs. gave 10·17 grs. sulphate of barytes and 3·68 grs. oxide of iron.
III. 14·135 grs. gave 8·47 grs.sulphate of barytes and 3·06 grs. oxide of iron.

The combustions were made with chromate of lead.

I. 11·735 grs. gave 7·730 grs. carbonic acid and 1·390 gr. water.
II. 10·610 grs. gave 7·145 grs. carbonic acid and 0·700 gr. water.
III. 14·045 grs. gave 8·800 grs. carbonic acid and 1·900 gr. water.

	I. 1st Crystallization.	II. 2nd Crystallization.	III. New portion.
Iron	15·16	16·27	14·76
Barium	35·57	37·59	37·85
Carbon	17·96	18·34	17·08
Hydrogen	1·31	0·73	1·50

But a new portion of barytes salt did not give the same result; the portion analysed was in prismatic crystals, and crystallized twice.

I. 11·65 grs. gave 6·58 grs. sulphate of barytes and 2·49 grs. oxide of iron.
II. 17·22 grs. gave 9·83 grs. sulphate of barytes and 3·58 grs. oxide of iron.

I. 6·87 grs. gave 3·87 grs. carbonic acid and 0·52 gr. water.
II. 13·62 grs. gave 7·44 grs. carbonic acid and 0·69 gr. water.

	IV. 1st Crystallization.	V. 2nd Crystallization.
Iron	14·96	14·55
Barium	33·23	33·60
Carbon	15·41	16·38
Hydrogen	0·83	0·55

Another portion, in flat prismatic crystals, made by neutralizing nitroprussic acid with carbonate of barytes, gave the following results:—

12·33 grs. gave 6·61 grs. sulphate of barytes and 2·42 grs. peroxide of iron.
6·60 grs. gave 4·005 grs. carbonic acid and 1·040 gr. water.

	VI.
Iron	13·73
Barium	31·53
Carbon	16·52
Hydrogen	1·75

In this case the salt lost no more in the water-bath, although this was to have been expected from its larger quantity of hydrogen.

In all these cases the specimens were excellently crystallized, and yet there is a

greater or less quantity of a foreign substance prevailing in all, and producing results so very discordant. In the first two portions analysed the barium is to the carbon (37·01 : 17·79) almost exactly as 1 equiv. : 5½ equivs., and the iron is to the carbon, sensibly though not so exactly, in the same proportion. In analysis VI., the iron is to the carbon as 28 : 33·7, or rather more than 1 : 5½, while the barium is to the carbon as 1 : 6. Again, in analyses IV. and V., the iron is to the carbon as 1 : 5, and the barium to the same element 1 : 5½.

Finally, it will be seen further on that the silver salt made from these altered salts of barium do not contain this excess of carbon. The filtrate from the silver salts yields on evaporation and incineration a small quantity of a black ash, but the quantity being so small the nature of the substance could not be ascertained. We can scarcely suppose that it is a ferrocyanide, because we should have expected to have it precipitated by nitrate of silver, even though it could not be recognized by its usual tests. It would be useless without further information to speculate upon the probable nature of the impurity. Sufficient however has been shown to prove that the most complicated results may attend the analysis of specimens of nitroprusside of barium prepared from solutions which have been heated and thus partially decomposed.

Altered Nitroprusside of Sodium.

23. The previous analyses of the crystallized nitroprussic acid and of the nitroprussides of ammonium and barium, and the composition of the silver salts prepared from them, show a want of accordance between the iron in the electro-negative constituent and the metal in the electro-positive one. The iron in all these cases is about half a per cent. in excess, therefore not sufficient to be considered as being in atomic proportion. It was thought, from the very distinct crystallization of the sodium salt, that this excess might not accompany it if prepared from the respective silver salts of the above compounds. Accordingly the silver salt was decomposed by an equivalent quantity of hydrochloric acid. The resulting solution was neutralized with carbonate of soda and crystallized. Analyses I. and II. were made on a salt thus prepared from crystallized nitroprusside of barium. Analysis III. on a salt similarly made from nitroprusside of ammonia. Again, when we refer to the action of caustic soda on the nitroprussides, it was obvious that by using a less quantity of the alkali than sufficed to effect the complete decomposition, a nitroprusside with a similar impurity in solution was to be expected.

Analysis IV. was made on a specimen thus prepared, and its accuracy is confirmed by a future analysis of a silver salt.

I. 13·695 grs. gave 3·72 grs. peroxide of iron.
II. 20·93 grs. gave 5·72 grs. peroxide of iron and 9·93 grs. sulphate of soda.
III. 15·35 grs. gave 4·25 grs. peroxide of iron and 7·10 grs. sulphate of soda.
IV. 11·13 grs. gave 3·07 grs. peroxide of iron and 5·06 grs. sulphate of soda.

The combustions were made with chromate of lead.

II. 13·34 grs. gave 9·74 grs. carbonic acid and 1·58 gr. water.
III. 14·475 grs. gave 10·68 grs. carbonic acid and 1·67 gr. water.
IV. 6·730 grs. gave 5·33 grs. carbonic acid and 1·01 gr. water.

	From barium salt.		From ammonium salt.	By action of caustic soda.
	I.	II.	III.	IV.
Iron	19·00	19·12	19·38	19·30
Sodium		15·37	15·00	14·72
Carbon		19·91	20·12	21·59
Hydrogen. . . .		1·31	1·21	1·65
Nitrogen . . Oxygen		44·39	44·29	42·74
		100·00	100·00	100·00

It will be seen from these analyses that the excess of iron still remains, and this is further confirmed by silver salts again made from them and analysed. It will also be observed that in specimen IV. we have the same remarkable increase in carbon as observed in the barium salt; the sodium is to the carbon as 1 : 5½, which is exactly the proportion found in the latter salt; but this excess of carbon does not go down with a silver salt made from it.

Examination of the Silver Salts made from the altered Nitroprussides.

24. To save unnecessary repetition, the numerous analyses made of the silver salts are here brought together, although it might have been more distinct to have introduced them under the respective salts from which they were made. The reason for converting them into silver salts was, that from the high atomic weight of silver and its accuracy of determination, the atomic accordance or disagreement between it and the iron could more readily be perceived.

Analyses I. II. and III. were made on three different preparations of silver salt made from three different specimens of crystallized nitroprussic acid, by adding the latter to nitrate of silver.

Analysis IV. was made upon a portion of II. treated on sand-bath with strong nitric acid in the hope of dissolving out the excess of iron. A very small quantity of iron was detected in solution by prusside of potassium.

Analysis V. was made on the silver salt prepared from crystallized nitroprusside of ammonia.

Analyses VI. and VII. from silver salt precipitated from crystallized nitroprusside of barium, which contained 17·96 grs. of carbon, or in which the barium was to the carbon as 1 : 5½.

Analysis VIII. On previous silver salt digested on the sand-bath with strong nitric acid to dissolve out excess of iron.

Analysis IX. On silver salt made from the crystallized sodium salt (No. 2) containing 19·91 grs. carbon.

Analysis X. Silver salt prepared from sodium salt (No. 4) containing 21·59 carbon, or in which the sodium was to the carbon as 1 : 5½. In order if possible to remove the excess of iron, the salt was first precipitated by sulphate of copper and washed, the copper salt was now decomposed by soda and crystallized, and the silver salt was precipitated from this newly-crystallized portion.

I. 19·605 grs. gave 3·77 grs. peroxide of iron and 12·86 grs. chloride of silver.
II. 16·795 grs. gave 3·24 grs. peroxide of iron and 10·94 grs. chloride of silver.
III. 13·580 grs. gave 2·60 grs. peroxide of iron and 8·79 grs. chloride of silver.
IV. 6·765 grs. gave 1·35 gr. peroxide of iron and 4·355 grs. chloride of silver.
V. 14·68 grs. gave 2·80 grs. peroxide of iron and 9·44 grs. chloride of silver.
VI. 13·16 grs. gave 2·43 grs. peroxide of iron and 8·535 grs. chloride of silver.
VII. 24·41 grs. gave 4·54 grs. peroxide of iron and 15·79 grs. chloride of silver.
VIII. 15·21 grs. gave 2·88 grs. peroxide of iron and 9·89 grs. chloride of silver.
IX. 13·60 grs. gave 2·60 grs. peroxide of iron and 8·80 grs. chloride of silver.
X. 8·81 grs. gave 1·69 gr. peroxide of iron and 5·59 grs. chloride of silver.

The combustions were made partly with chromate of lead, partly with oxide of copper.

I. 12·05 grs. gave 6·08 grs. carbonic acid and 0·10 gr. water.
II. 12·195 grs. gave 6·10 grs. carbonic acid and 0·08 gr. water.
IV. 8·10 grs. gave 4·03 grs. carbonic acid and 0·09 gr. water.
V. 10·35 grs. gave 5·13 grs. carbonic acid and 0·21 gr. water.
VI. 14·52 grs. gave 7·18 grs. carbonic acid and 0·05 gr. water.
VIII. 9·56 grs. gave 4·85 grs. carbonic acid and 0·04 gr. water.
IX. 10·835 grs. gave 5·50 grs. carbonic acid and 0·10 gr. water.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	Mean.
Iron	13·46	13·50	13·40	13·97	13·35	12·92	13·01	13·25	13·38	13·42	13·36
Silver	49·42	49·02	48·71	48·46	49·50	48·67	48·69	48·93	48·70	47·77	48·78
Carbon.....	13·75	13·64	.....	13·56	13·43	13·48	.....	13·82	13·84	.....	13·64
Hydrogen	0·09	0·07	.....	0·12	0·22	0·03	.....	0·04	0·10	.....	0·09
Nitrogen, Oxygen	23·28	23·77	.....	23·89	23·50	24·90	.....	23·96	23·98	.....	24·13
	100·00	100·00		100·00	100·00	100·00		100·00	100·00		100·00

If we assume the mean iron, 13·36, to represent the true quantity, then the silver to correspond to it in atomic proportion should have been 51·53, whereas there is only 48·78. Hence there is 0·72 of iron in excess over the equivalent quantity; this excess corresponds to $\frac{1}{15}$th of an equivalent. Again, supposing the carbon to be in the same proportion to the silver as in the nitroprussides, there should have been 13·0, so that there is an excess of 0·64. The excess of iron and of carbon is therefore almost exactly as 1 equiv. : 4 equivs., or viewing the carbon as representing cyanogen as 1 : 2. On this view the amount of impurity in the silver salt is 2·10 per cent. Calculating the mean analysis deprived of this supposed impurity, we have

		Theory of nitroprusside of silver.
Iron	12·92	13·01
Silver	49·81	50·18
Carbon	13·28	13·38
Hydrogen . . .	0·097	0·18
Nitrogen } Oxygen } . .	23·02	23·25
	100·00	100·00

In the previous calculation the cyanide supposed to be present is $Fe\,Cy_2$; this only denotes the proportion of iron to the cyanogen; it is possible though less probable that it might be $2(Fe\,Cy + HCy)$. In this case we might suppose the analysed silver salts to contain this cyanide somewhat in the following proportion: 7 equivs. nitroprusside to 1 equiv. of the supposed cyanide. On this supposition the calculated and actual numbers would be as follows:—

	Calculated.	Mean.
Iron	13·50	13·36
Silver	49·26	48·78
Carbon	13·76	13·64
Hydrogen . . .	0·20	0·09

It is not however to be supposed that this cyanide is present as a chemical compound in the above proportion, as the differences in the analyses show that it occurs in varying and not very definite proportions.

It would indeed appear that the barium and sodium nitroprusside contained a body in which the iron and cyanogen are in the same proportion as in ferrocyanogen ($Fe\,Cy_3$). But as the silver salt precipitated from them does not contain an excess of carbon, it can scarcely be supposed that this would not be precipitated. But in fact there are no data further than the mere ultimate analyses upon which reasoning can be founded with regard to this dissolved and combined foreign substance in the partially decomposed nitroprussides. As however all their essential characters and their crystalline form remain altogether unaltered, we cannot view the foreign substances as more than accidental.

Section IV.—*Action of Caustic Alkalies on the Nitroprussides.*

25. When a dissolved caustic alkali, such as potash or soda, is added to a solution of a nitroprusside, the dark red colour of the solution changes to an orange-yellow. If both solutions have been moderately dilute, no oxide of iron is precipitated, nor is ammonia evolved. The addition of alcohol to the orange-yellow liquid causes the precipitation of an aqueous solution of a new salt. This salt may be procured in a solid state as follows. Nitroprusside of potassium is dissolved in water and double its volume of alcohol is added. Caustic potash is now added to this solution, and a yellow curdy precipitate is obtained. This precipitate is washed with alcohol to free it from an excess of either of the reagents, but it is almost impossible to remove the last traces.

The salt is now pressed between folds of bibulous paper and dried *in vacuo* over sulphuric acid. It may be called nitroprusside of potassium and potash.

This salt is of a bright yellow colour and of crystalline appearance. It is very sparingly soluble in alcohol, but very soluble in water, to which it gives a strong alkaline reaction. It precipitates salts of lead of a fine yellow colour like the chromate of lead. Salts of iron are precipitated of a yellowish brown, and salts of copper of a brown colour. On the addition of an acid, the excess of potash is removed and nitroprusside of potassium remains in solution; the salt therefore is a compound of a nitroprusside with potash. It will not crystallize *in vacuo*, its solution decomposing with the deposition of an oxide of iron, and with the escape of a gas which communicates a pink colour to the sulphuric acid used for the evaporation in the air-pump. The salt heated in a tube evolves nitric oxide and ammonia, and leaves a black residue which yields to water an alkaline solution of a nitroprusside. When its solution in water is boiled, complete decomposition takes place, a ferrocyanide, oxide of iron, nitrite and oxalate of potash being produced.

It is almost impossible to obtain it free from uncombined nitroprusside, which is observed to remain in solution when a salt of lead is added to it. If potash in excess be used, it is equally difficult to remove the excess by washing. The analyses therefore give only approximative results; they were made in the usual way by decomposing the salt with fuming sulphuric acid.

I. 17·350 grs. gave 3·440 grs. peroxide of iron and 14·32 grs. sulphate of potash.

II. 37·870 grs. gave 7·345 grs. peroxide of iron and 30·53 grs. sulphate of potash.

The combustions were made with chromate of lead.

I. 14·075 grs. gave 7·765 grs. carbonic acid and 1·015 gr. water.

II. 13·71 grs. gave 7·490 grs. carbonic acid and 0·985 gr. water.

The samples of salt analysed were made at different times.

	I.	II.	Mean.			Calculated.
Iron	13·87	13·57	13·72	5	140	14·38
Potassium . .	37·00	36·14	36·57	9	351	36·07
Carbon . .	15·04	14·89	14·96	24	144	14·79
Hydrogen .	0·80	0·79	0·79	8	8	0·82
Nitrogen } . .	33·29	34·61	33·96	15	210	33·94
Oxygen }				15	120	
	100·00	100·00	100·00		973	100·00

Hence this salt differs from nitroprusside of potassium by containing 4 atoms of potash attached. Its formula is therefore $Fe_5\ Cy_{12}\ 3NO\ K_5 + 4KO + 8HO$. There is little doubt that it might, when quite free from nitroprusside, contain an additional equivalent of potash.

It has been stated that a solution of this salt is decomposed on boiling. Oxide of iron falls down, nitrogen escapes, and the solution is now found to contain ferrocyanide of potassium, nitrite of potash and traces of oxalate of potash.

26. The products of transformation were determined (1) by precipitating the ferrocyanide by alcohol; (2) by adding nitrate of lime to precipitate the oxalate*, which was always accompanied by a minute quantity of a pink compound containing cyanogen and iron; (3) by examining the liquid which remained, and was found to evolve nitric oxide on the addition of an acid. It gave a precipitate with nitrate of silver, which, though sparingly soluble in cold water, dissolved in hot water and crystallized on cooling; 13·25 grs. of the crystalline salt thus obtained, treated with hydrochloric acid, gave 12·33 grs. chloride of silver, or 70·03 per cent. Nitrite of silver (AgO, NO_3) contains 70·12 per cent.

In examining the relative quantities of these products of transformation, recourse was first had to the yellow salt itself. But as this generally contained a little nitroprusside, and as the products of decomposition varied with the period of ebullition, on account of the slower action from the insufficient quantity of alkali, it was found more accurate to examine the transformations by acting upon a solution of nitroprusside with an excess of alkali. Without therefore giving the details of the experiments on the yellow salt itself, some of the general results may be stated; from these it will be seen that the quantities of oxide of iron and of prusside produced vary according to the conditions of the experiment, principally according to the longer or shorter period of ebullition. 100 parts of the yellow salt gave, on boiling its aqueous solution,—

	I.	II.	III.	IV.	V.
Peroxide of iron	3·0	3·58	3·0	3·56	2·71
Ferrocyanide of potassium .	60·86	60·59	59·48	68·83	64·50

In all these cases there was more or less nitroprusside of potassium undecomposed. The amount of oxalate of potash found in solution varied from 0·97 to 1·5 per cent.

The transformation was now examined in the following manner. A weighed quantity of a nitroprusside was dissolved in water and boiled, caustic potash or caustic soda (according as the nitroprusside was a salt of potassium or sodium) being added to the boiling solution, until a drop taken out gave, after being neutralized, no purple colour with a sulphide. The precipitated oxide of iron was now collected and weighed. The filtrate was precipitated by alcohol, and the prusside collected and determined on a weighed filter. The filtrate was now neutralized with acetic acid, and chloride of calcium added, but the oxalate of lime was generally not in sufficient quantity to collect and weigh, mere traces being obtained. It was now attempted to estimate the amount of nitrate by the process described by Nesbit for analysing nitrates†, that is, by converting its nitrogen into ammonia by zinc and muriatic acid, the hydrogen being slowly evolved. The ammonia thus formed was separated

* To prove that this was an oxalate, a portion was precipitated by nitrate of lead from the solution after precipitation by alcohol. The precipitate was of a pink colour, and was now decomposed by sulphuretted hydrogen, neutralized by pure carbonate of soda, and again precipitated as a lead salt, which was now quite white. Calcined with nitrate of ammonia, 1·660 gr. gave 1·250 gr. oxide of lead, or 75·3 per cent. Oxalate of lead contains 75·5 per cent.

† Memoirs of Chemical Society.

by distillation with caustic soda, collected in muriatic acid and determined as chloride of platinum and ammonia. This process did not however give constant results in my hands, probably from the difficulty of preventing the escape of nitric oxide on adding an acid to the nitrite. The nitrite was therefore determined by loss. In one case only did I, by the above process, obtain a result approaching the quantity of nitrite in solution.

17·24 grs. of nitroprusside of sodium were dissolved in water, the solution was boiled and caustic soda added, keeping the solution distinctly alkaline after ebullition had continued for some time. It yielded 0·92 gr. peroxide of iron, and 14·85 grs. ferrocyanide of sodium; the residual liquid, treated according to NESBIT's plan, only gave 2·57 grs. platinum salt.

Iron precipitated	3·73 per cent.
Iron in prusside	15·08 per cent.
	18·81

Hence all the iron, except about 0·5 per cent., is found in the oxide of iron and in the prusside; the remainder is probably in the minute quantity of pink salt alluded to above. The carbon contained in the prusside amounts to 20·3; so that the total quantity of cyanogen has gone down in that form, the carbon in the nitroprusside being 20·0 per cent.

It will be seen that the iron precipitated as peroxide of iron is one-fourth that retained in the ferrocyanide. The following equation expresses the transformation:—

$$2(Fe_5\,Cy_{12}\,3NO,\,Na_5)+9NaO=4(Fe_2\,Cy_6\,Na_4)+3NaO,\,NO_3+Fe_2\,O_3+3N.$$

Or expressed in another way,—

4 equivs. ferrocyanide of sodium . . .	$Fe_8\ Cy_{24}\ Na_{16}$
3 equivs. nitrite of soda	$Na_3\ N_3\ O_{12}$
1 equiv. peroxide of iron	$Fe_2\ O_3$
3 equivs. nitrogen	N_3

$$2\text{ equivs. nitroprusside}+9\text{ of soda}=Fe_{10}\,Cy_{24}\,Na_{19}\,N_6\,O_{15}$$

The first change is obviously to form ferrocyanide of sodium, 6 equivs. of oxygen passing over to the nitrous oxide; this, with the oxygen in the latter, would make 4 equivs. nitrous acid; but the 2 equivs. of iron liberated require 3 of oxygen to form peroxide, which it receives at the expense of the nitrous acid, leaving therefore 3 equivs. of that acid to unite with soda, the remaining 3 equivs of nitrogen escaping as a gas. During the ebullition no ammonia can be detected, either by smell or by turmeric paper.

SECTION V.—*Action of an Alkaline Sulphide on a Nitroprusside.*

27. It has been repeatedly mentioned, that when solutions of nitroprusside of potassium or sodium and of the corresponding sulphides are mixed together, the most magnificent purple colour is produced. This colour however is very transitory and cannot be preserved in an aqueous solution. The purple or blue compound may

however be obtained in a solid state when alcoholic solutions of the two salts are employed. In order to obtain it in this state, nitroprusside of sodium is dissolved in the smallest possible quantity of water, and to this solution is added four or five times its bulk of alcohol. An alcoholic solution of neutral sulphide of sodium (the sulphide obtained by reducing the sulphate with hydrogen) is now added to the alcoholic solution of nitroprusside, the addition being stopped before the supernatant liquid gives a decidedly black reaction on lead paper. The mixed solutions acquire a magnificent purple blue colour. On stirring the mixture, an aqueous solution of the purple compound falls down in oily drops. After this has settled, the alcohol is decanted, and the blue solution is washed repeatedly and quickly with alcohol by decantation. It is now, as rapidly as possible, put *in vacuo* over sulphuric acid, when it soon parts with its water and becomes solid. It usually dries to a dirty green powder, which is a mixture of the purple compound with the products of its decomposition. It may however, though this is rare, dry quite unchanged in its character, being still of a fine blue colour and dissolving entirely in water with all its magnificent purple blue shade. It cannot then be dried in the water-bath, where it quickly decomposes and becomes green.

The following analysis was made on two portions which were dried in the air-pump, until they ceased to lose weight and had all their properties unchanged. They were oxidized by nitrate of ammonia; the residue was dissolved in nitric acid. The iron was precipitated as peroxide, the sulphur estimated as sulphate of barytes, and the soda as a sulphate.

I. 14·210 grs. gave 3·420 grs. peroxide of iron, 5·710 grs. sulphate of barytes and 9·38 grs. sulphate of soda.

II. 8·99 grs. gave 3·88 grs. sulphate of barytes and 6·62 grs. sulphate of soda, the iron being accidentally lost.

The combustion was made by chromate of lead, peroxide of lead being used to arrest the sulphurous acid.

I. 6·20 grs. gave 3·855 grs. carbonic acid and 0·440 gr. water.

II. 10·565 grs. gave 6·810 grs. carbonic acid and 0·675 gr. water.

	I.	II.	Mean.
Iron	16·84	16·84	16·84 *
Sodium	21·37	23·84	22·60
Sulphur	5·51	5·92	5·71
Carbon	16·95	17·58	17·27
Hydrogen	0·78	0·71	0·74
Nitrogen, Oxygen	38·55	35·11	36·84
	100·00	100·00	100·00

* It should be stated that in many analyses of this compound in its partially decomposed state, the most discordant results were obtained. The two analyses here adduced were made on the only specimens which appeared to be unchanged; in all the other cases the compound had become green and therefore was decomposed, as it no longer dissolved in water with its characteristic purple tint.

In such a variable compound as this, close results can scarcely be looked for in two analyses. As an approximation, however, it will be seen that the iron is to the sodium as 5 : 8, and to the sulphur as 5 : 3.

The blue unchanged compound gives with protosulphate of iron a beautiful precipitate of the same purple blue colour as itself, but this is decomposed by washing. With salts of lead it gives a brownish yellow precipitate, with salts of copper a brown precipitate, both these being obviously products of decomposition.

28. The purple blue compound dissolved in water speedily becomes red, and when in this state, a salt of lead throws down a pinkish red precipitate. This red solution however soon decomposes, a brownish precipitate falling, and the yellow colour due to a prusside being seen in the solution. If the sulphide originally employed contained sulphuretted hydrogen, a soluble prussian blue is also found in the liquid. During these changes, ammonia, hydrocyanic acid, and a gas possessing the properties of nitrogen are given off. In fact, on mixing the solutions of sulphide and nitroprusside, it is difficult, even by keeping the solutions quite cold, to prevent the formation of a little ammonia and escape of nitrogen. The solution of the purple compound in water decomposes even under the air-pump, depositing the brown precipitate, and it does so immediately when it is boiled.

When the solution is filtered from the brown precipitate, the addition of alcohol separates ferrocyanide of sodium. The alcoholic filtrate strikes a blood-red colour with a persalt of iron, and with sulphuric acid evolves nitric oxide, which is immediately rendered sensible by a protosalt of iron, a nitrite being thus shown to be in solution. Ammonia cannot be detected in the solution, neither does it appear to any great extent when the transformation takes place in the cold, though it always does so when ebullition is used to hasten the transformation. It therefore appears to be the product of an after action.

The brown precipitate is first to be examined. It is found to consist of peroxide of iron and sulphur, the latter remaining when the former is dissolved out by an acid. It was analysed by oxidation with nitromuriatic acid. 7·21 grs. gave 16·90 grs. sulphate of barytes, equal to 2·33 grs. of sulphur, and 4·22 grs. peroxide of iron, the rest being water. Hence the proportion of sulphur to iron in equivalents is nearly as 4 : 3 ; the proportion for 2·33 sulphur would yield 3·0 iron, while 2·95 was found by the experiment.

It was now desirable to ascertain what proportion of iron was thrown down as ferrocyanide and how much remained in the brown precipitate. For this purpose a portion of a preparation, which had become green by standing in the air-pump, was first analysed in order to ascertain the relative proportion of its constituents, and it was then dissolved in water and boiled.

14·41 grs. gave 6·93 grs. sulphate of barytes, 17·68 grs. gave 3·55 grs. peroxide of iron and 10·00 grs. sulphate of soda. 6·025 grs. gave 3·31 grs. carbonic acid and

0·820 gr. water. Hence this changed purple compound, before complete transformation, contained in 100 parts,—

Iron	14·05
Sodium	18·33
Sulphur.	6·59
Carbon	14·98
Hydrogen	1·51
Nitrogen, Oxygen	44·54
	100·00

11·31 grs. were now boiled in water, and 0·94 gr. of the brown precipitate was obtained by filtration, and 5·90 grs. of prusside of sodium were precipitated by alcohol. Hence of the total quantity of 1·58 gr. of iron present 1·08 gr. was found in the ferrocyanide, the remainder being in the brown precipitate. As the ferrocyanide of sodium is of constant composition, which the brown mixture is not, the iron in the latter is here estimated by loss and would amount to 0·50 gr. The proportion in equivalents is nearly, though not exactly, as 7 : 3, which would have made the iron in the brown precipitate 0·46 gr. instead of 0·50 gr..

Taking these proportions as leading to a general view of the transformation, it may be expressed by the following equation:—

$$2(Fe_5\,Cy_{12}\,3NO+8Na+3S)+2HO=7(Na_2\,Fe\,Cy_3)+(Na,\,Cy\,S_2)+(Na\,O,\,NO_3)+Fe_3\,O_4+S_4+2HCy+2N.$$

The only point in which this transformation does not agree with experiment, is in the supposed production of ferrous-ferric oxide, whereas, when the brown precipitate is washed with acid, only peroxide of iron unaccompanied by protoxide of iron passes through. It is therefore probable that the oxidation of this oxide may give rise to the small quantity of ammonia observed, the oxygen from decomposed water uniting with it, and the nascent hydrogen with nitrogen to form ammonia. Allowing this to be the explanation of the disagreement with experiment, the following scheme may render the above equation more immediately intelligible. Two equivalents of the blue compound with 2 equivs. of water, by boiling, are resolved into—

7 equivs. ferrocyanide of sodium.
1 equiv. sulphocyanide of sodium.
1 equiv. nitrite of soda.
1 equiv. oxide of iron ($FeO+Fe_2O_3$).
4 equivs. sulphur.
2 equivs. hydrocyanic acid.
2 equivs. nitrogen.

And probably the ferroso-ferric oxide is transformed at the expense of the oxygen of water into ferric oxide, the hydrogen forming ammonia with nitrogen,

$$6FeO+3HO+N=3Fe_2O_3+NH_3.$$

29. In giving the above equation, the blue sulphur compound was supposed to consist of nitroprusside of sodium with 3 equivs. of sulphuret of sodium attached. The following calculation shows that this is an expression of the analysis:—

		Calculated.	Mean experiment.
5 Iron . . .	140	17·36	16·84
8 Sodium . .	186	23·07	22·60
24 Carbon . .	144	17·86	17·27
3 Sulphur . .	48	5·95	5·71
6 Hydrogen .	6	0·74	0·74
15 Nitrogen . .	210	35·02	36·84
9 Oxygen . .	72		
	806	100·00	100·00

The approximation is sufficiently near when the difficulty of getting the substance in at all a stable state is considered. Two views might be taken of the constitution of this singular compound (1), that it is nitroprusside of sodium with 3 equivs. of sulphuret of sodium attached—

$$Fe_5\,Cy_{12}\,3NO,\,5Na+3NaS+6HO;$$

but this would scarcely account for its extreme facility of decomposition; it may therefore be supposed that caustic soda is attached to the salt, as we have seen that it can be, in studying the action of alkalies on the nitroprussides, and that the sulphur has taken the place of the oxygen, thus:—

$$Fe_5\,Cy_{12}\,3NS,\,5Na+3NaO+6HO.$$

Either of these formulæ would suit the analysis; in support of the latter may be adduced the fact observed by Gregory, that sulphuret of nitrogen in the presence of caustic alkalies acquires a deep transitory amethyst colour, which, on disappearing, evolved ammonia, a description exactly accordant with the present case.

Action of Sulphuretted Hydrogen on the Nitroprussides.

30. Sulphuretted hydrogen decomposes the soluble nitroprussides. The products of transformation are most conveniently obtained in the following way:—Nitroprusside of sodium is dissolved in the smallest possible quantity of cold water, and three or four times its volume of alcohol is added to the solution. Sulphuretted hydrogen is now passed through this alcoholic solution. Sulphur, prussian blue, and ferrocyanide of sodium, are very gradually precipitated; the action, however, is very slow, and must be long continued. The alcoholic solution is now of a reddish olive-brown colour. When the sulphuretted hydrogen has ceased to act, this supernatant brownish liquid gives no coloration when mixed with an alkaline sulphide.

If allowed to stand for a few hours, it deposits a little of the precipitates which it held in solution. After this the brown solution is found to contain neither ferrocyanide nor nitroprusside of sodium; a persalt of iron is slightly deepened in colour when mixed with it, showing the presence of a mere trace of a sulphocyanide. When this reddish-brown solution is evaporated in the water-bath, it deposits oxide of iron and sulphur, and becomes decomposed. Evaporated *in vacuo* over sulphuric acid it deposits, when nearly dry, black crystalline needles, but these seem to be a product of decomposition, and are mixed with oxide of iron and other substances; attempts were therefore made to ascertain the composition of the original substance by precipitating its solution by metallic salts. Bichloride of mercury produces a brown precipitate, sulphate of copper a pinkish brown, and nitrate of silver a black precipitate. But these were obviously products of decomposition, for during the precipitation nitric oxide is abundantly evolved. This is especially the case in the precipitate with silver. If that precipitate, after being washed, be now mixed with a small quantity of hydrochloric acid to take up the silver, sulphuretted hydrogen is evolved, protochloride of iron and abundance of sulphocyanic acid are now found in solution; the first is recognized by the prussian blue formed on adding red prusside of potassium, the second by the blood-red colour which it strikes with perchloride of iron. When nitrate of silver is added to the red-brown solution, the black precipitate already alluded to falls down, but at the same time the supernatant liquor had a reddish brown colour; on examining this it was found to contain a persalt and protosalt of iron, the dark coloration being due to the escaping nitric oxide. The amount of sulphur precipitated during the passage of sulphuretted hydrogen through the nitroprusside is about 17 per cent.; the amount of ferrocyanide of sodium and of prussian blue has been found to vary much.

From the difficulty of obtaining the products of transformation in a pure state, I have not yet been able to make direct quantitative examinations of the various substances formed; it is therefore impossible to express the transformation in the form of an equation. From some experiments now in progress, I trust, however, to overcome those difficulties which have prevented the completion of this study in time for the presentation of this paper.

On the Constitution of the Nitroprussides.

31. In the preceding part of the paper the analyses of the nitroprussides led to the extremely complicated formula $Fe_5 C_{24} N_{15} O_3 R_5$. This formula was *à priori* very improbable, and naturally led to the belief that an error in the estimation of the carbon forced its adoption. In fact, if 25 instead of 24 equivs. of carbon were present, the formula would resolve itself into the much simpler expression $Fe_2 C_{10} N_6 O R_2$. It is therefore important to review the evidence, in order to see whether the simple proportion of iron to carbon, 1 : 5, might be derived from it. The following table exhibits the proportion of iron and carbon found in the analyses of the respective salts:—

Name of salt.	Number of analyses furnishing the mean.	Quantity of iron. Mean.	Quantity of carbon. Mean.	Atomic relation of iron to carbon.
Nitroprusside of sodium	9	19·54	20·03	28 : 28·7
Nitroprusside of potassium	5	19·05	19·63	28 : 28·8
Nitroprusside of ammonium	3	22·08	22·69	28 : 28·7
Nitroprusside of silver	4	13·03	13·29	28 : 28·5
Nitroprusside of copper	4	20·45	21·25	28 : 29·0
Nitroprusside of iron.....	3	19·09	19·96	28 : 29·2
Nitroprusside of zinc.....	1	20·07	20·53	28 : 28·6
Nitroprusside of calcium	1	21·09	21·47	28 : 28·5
Nitroprusside of barium	2	14·10	14·98	28 : 29·7
Nitroprussic acid	3	23·80	24·80	28 : 29·1
Mean of the whole.....	35	192·30	198·63	28 : 28·9

Now the proportion of 1 equiv. of iron to 5 equivs. of carbon would require the proportion 28 : 30. This difference is too great to be due to any errors of observation, especially when it is remembered that these, in the case of a body containing much nitrogen, tend to increase and not to diminish the apparent quantity of carbon. The actual proportion found, 28 : 28·9, indicates, in equivalents, 5 equivs. iron to 24 equivs. carbon; this proportion would require 28 : 28·8; the slight excess found is in the direction of the known errors of observation.

These considerations forced the adoption of the complex formula given above. It will also be seen, from an examination of the analytical details, that the quantity of nitrogen corresponds to 6 equivs. for every 10 equivs. of carbon, or 15 equivs. for the 24 equivs. of carbon required by the formula. As 12 of these are in the state of cyanogen, as shown both by the transformation of the nitroprussides by alkalies and by sulphides, the remaining 3 equivs. must be in the form of an oxide of nitrogen. But the loss on the analyses does not admit the supposition that the oxide is nitric oxide, as might have been supposed, neither do the transformations countenance this idea. The oxygen is in the proportion of 3 equivs. for every 3 equivs. of nitrogen; the nitrogen not present as cyanogen must exist as nitrous oxide. This is unusual, and its functions must therefore be inquired into. It will at once be seen that if nitrous oxide is supposed to substitute and play the part of cyanogen, the iron and the non-electro-negative bodies with which it is associated are present in the same proportion as in the hypothetical radical ferrocyanogen; 5 equivs. ferrocyanogen have the formula $Fe_5\ Cy_{15}$; 1 equiv. of nitro-ferrocyanogen has the formula $Fe_5\ Cy_{12}\ 3NO$. The nitroprussides are therefore supposed to contain a ferrocyanogen in which 3 equivs. of cyanogen are substituted by 3 equivs. of nitrous oxide.

32. But the proportion of the electro-positive element in the nitroprussides is less than that existing either in the ferrocyanides or ferridcyanides. Liebig supposes these two latter compounds to differ by containing different radicals, one being twice the atomic weight of the other. It would be equally instructive to suppose that they both contain the same radical, but that, as in the case of the different phosphoric acids, one is quadribasic, while the other is tribasic.

Quadribasic prussides, $Fe_2\,Cy_6+4R$, formula of ferrocyanides.
Tribasic prussides . . . $Fe_2\,Cy_6+3R$, formula of ferridcyanides.
Bibasic prussides . . . . $Fe_2\,Cy_6+2R$, formula of undescribed compounds.

With regard to the last class, its existence must be yet considered hypothetical, but in searching for it, I have received sufficient encouragement to enable me to hope that I shall very shortly be able to establish it. Without presenting the analytical evidence to this effect, it can only be adduced as a probable hypothesis to explain the nitroprussides. The latter class of salts may be supposed to correspond to a bibasic class of prussides in which part of the cyanogen is replaced by nitrous oxide. Thus $5(Fe\,Cy_3+R)=Fe_5\,Cy_{15}+5R$ correspond to 1 equiv. of a nitroprusside, $Fe_5\,Cy_{12}\,3NO+5R$. The great approximation of the latter formula to the more simple expression $Fe_2\,Cy_5\,NO+2R$, renders it singular that the small deficiency of carbon refuses to allow the formula to be thus expressed. In such a case this supposed bibasic prusside and the nitroprusside would stand in a very simple relation:

$$Fe_2\,Cy_6 \quad +2R,$$
$$Fe_2\,Cy_5\,NO+2R.$$

The complicated formula required by the analyses of all the nitroprussides might be resolved into $2(Fe_2\,Cy_5\,NO+2R)+(Fe\,Cy_2\,NO+R)$, in which the latter member is constituted on the same type, but more cyanogen is displaced by the nitrous oxide. It will not excite surprise, after what has been learned in the previous inquiry as to the obstinate manner in which the nitroprussides unite with cyanides from which they are not removable by any means tried, that a salt constituted on the same type should unite with the true nitroprussides and form an integrant conjugate compound which is not broken up by crystallization. It appears therefore very probable that the true formula of the nitroprussides may in reality be $Fe_2\,Cy_5\,NO+2R$, and that further research may eliminate this compound. Hitherto this has not been done, and the only formula which correctly expresses the analysis is $Fe_5\,Cy_{12}\,3NO+5R$, which on theoretical, but on no other grounds, may be resolved into

$$2(Fe_2\,Cy_5\,NO+2R)+(Fe\,Cy_2\,NO+R).$$

I trust soon to be able to present to the Society another memoir on the prussides, which will confirm experimentally some of the views theoretically supported in the present communication; but at present I submit the previous results with a view of drawing attention to this interesting class of salts, and with a perfect conviction that future research will simplify and explain the remarkably complex and unsatisfactory formulæ which I have been obliged to adopt, without believing them to be the correct expression of the constitution of the salts.

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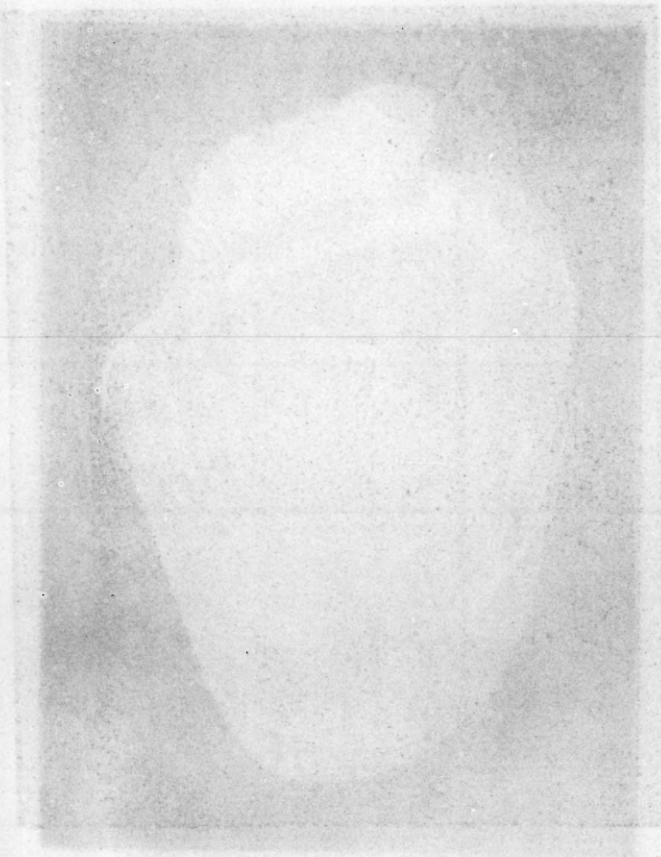

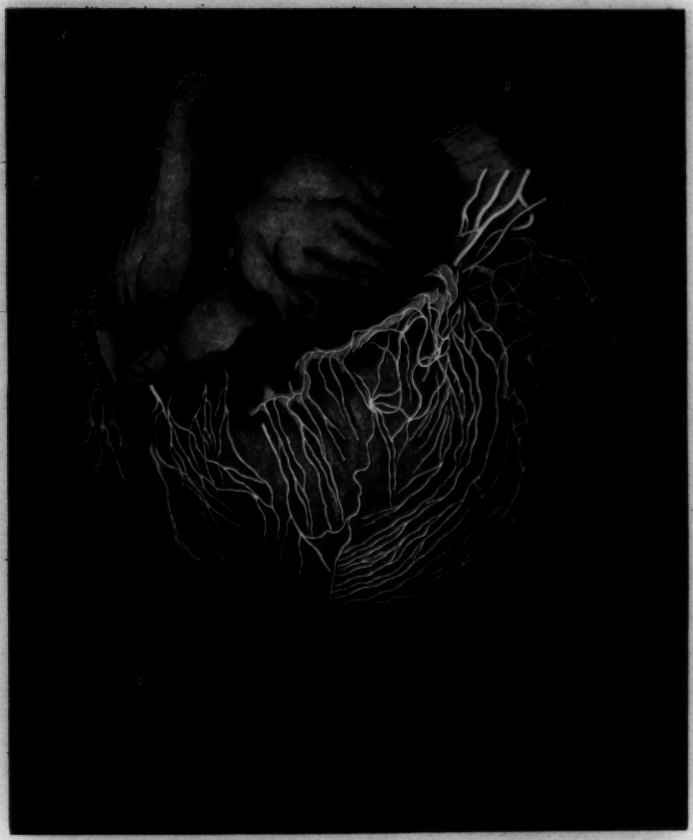

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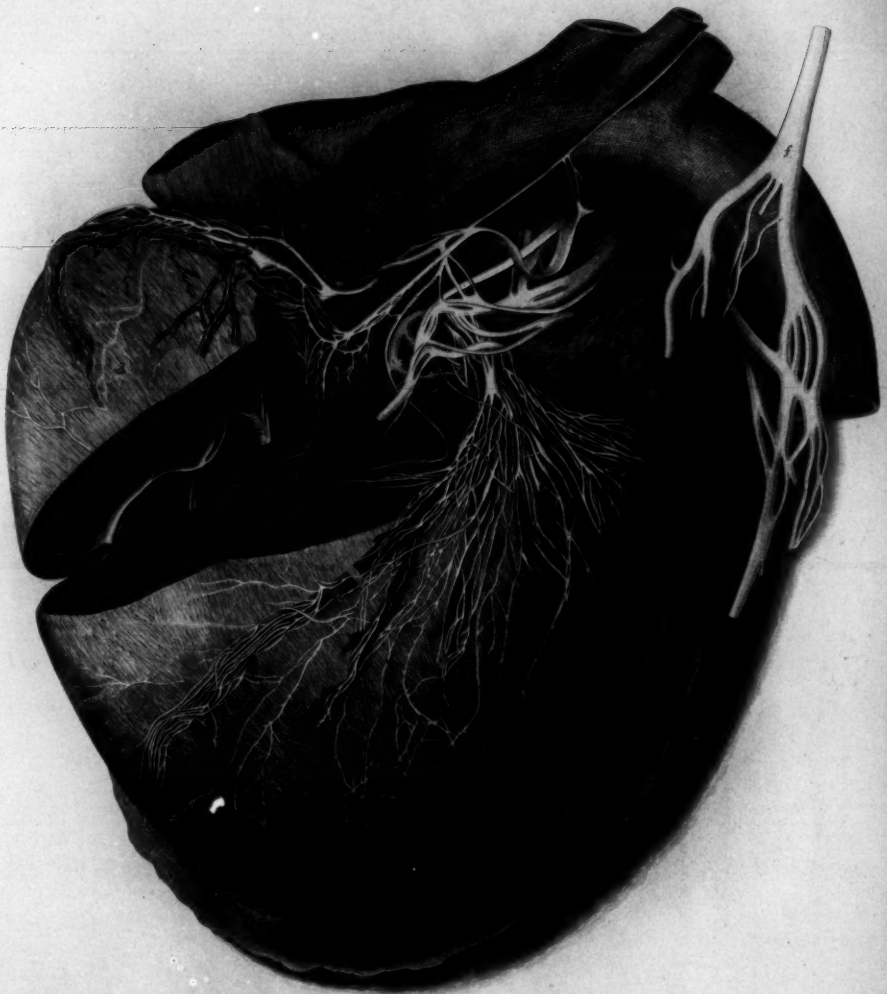

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Birmingham Wire.
MIDNIGHT
3AM.
6AM.
9AM.
NOON
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May 25. 1847.
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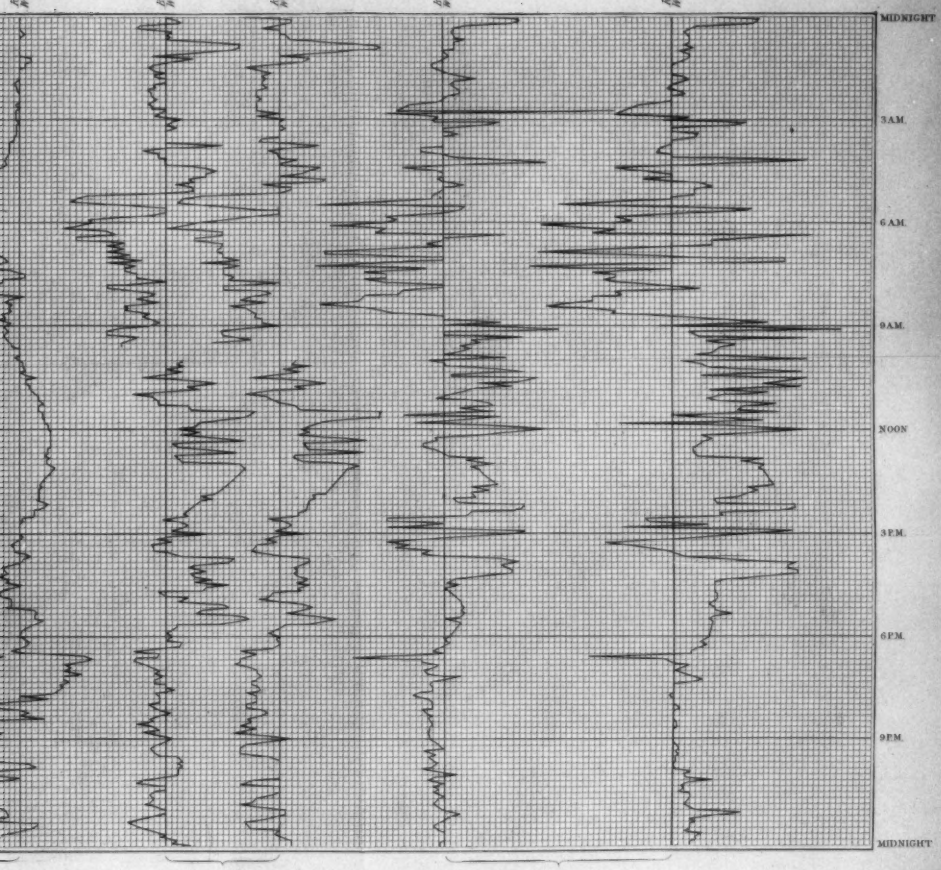

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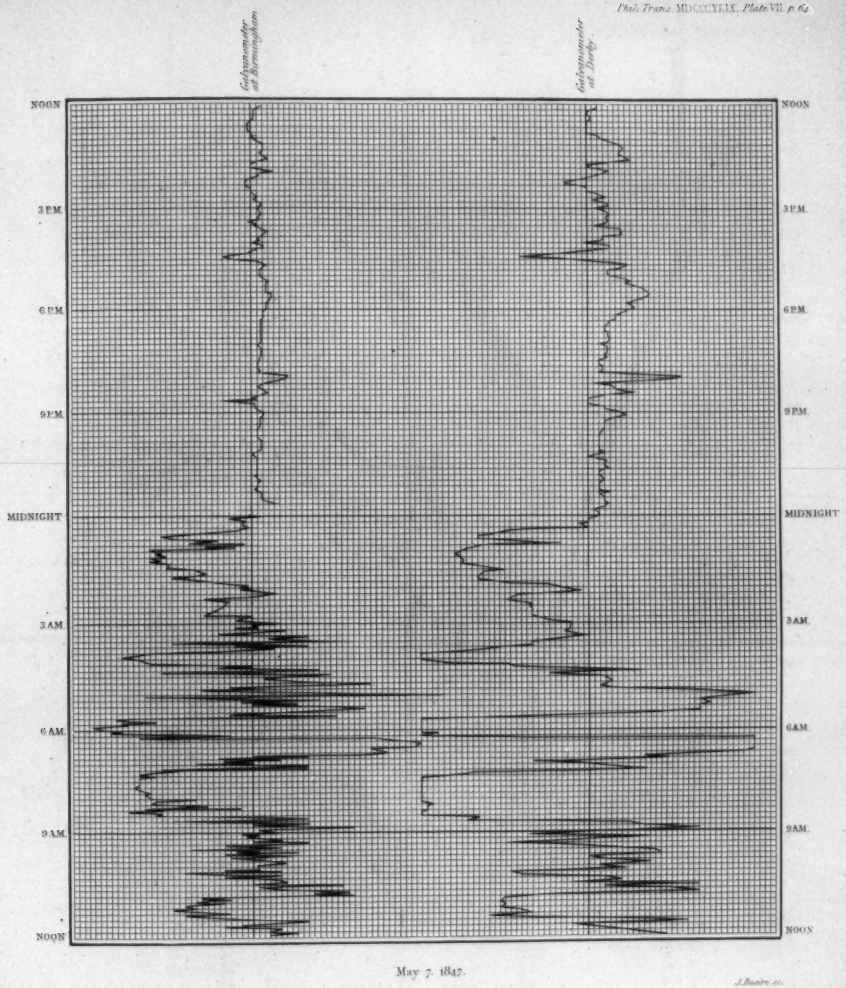

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bearing S. 21° W.
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bearing S. 8° W.
9 A.M.
10 A.M.
11 A.M.
NOON
1 P.M.
2 P.M.
3 P.M.
4 P.M.
5 P.M.
6 P.M.
N° 1 Wire
Observations
taken May 1 1849
N° 2 Wire
N° 1 Wire
Observations
taken May 3.

Derby to Leicester bearing S. 34° E.
Derby to Willington bearing S. W.
Derby to Leicester bearing S. 34° E.
Derby to Willington bearing S. W.
Derby to Kegworth bearing S. 68° E.
9 A.M.
10 A.M.
11 A.M.
NOON
1 P.M.
2 P.M.
3 P.M.
4 P.M.
5 P.M.
6 P.M.
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No 1 Wire
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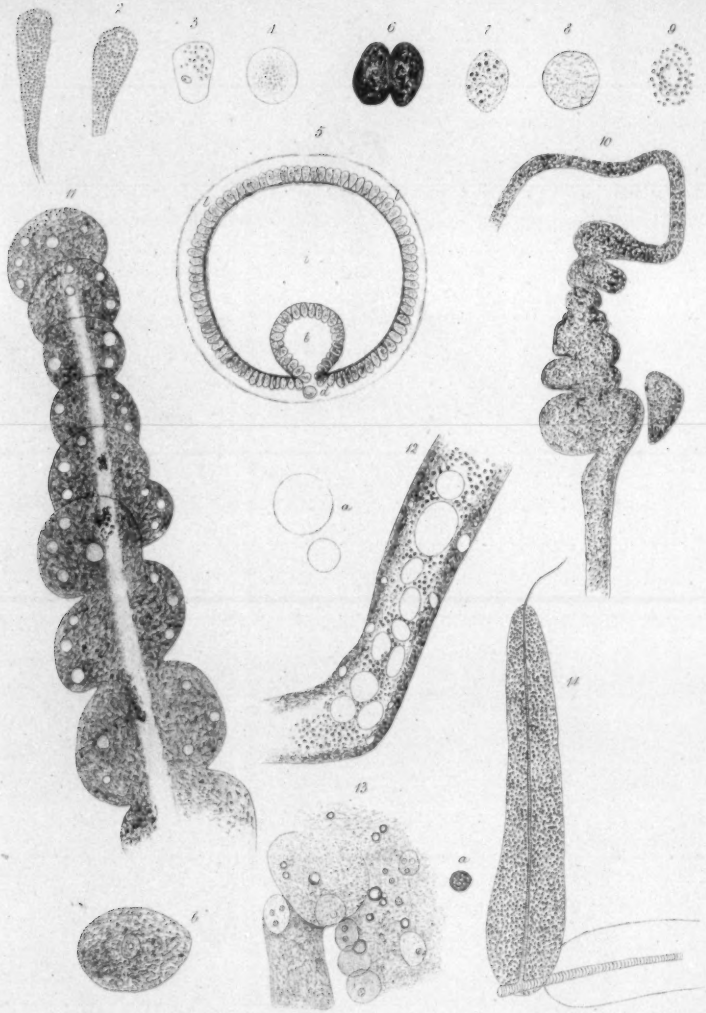
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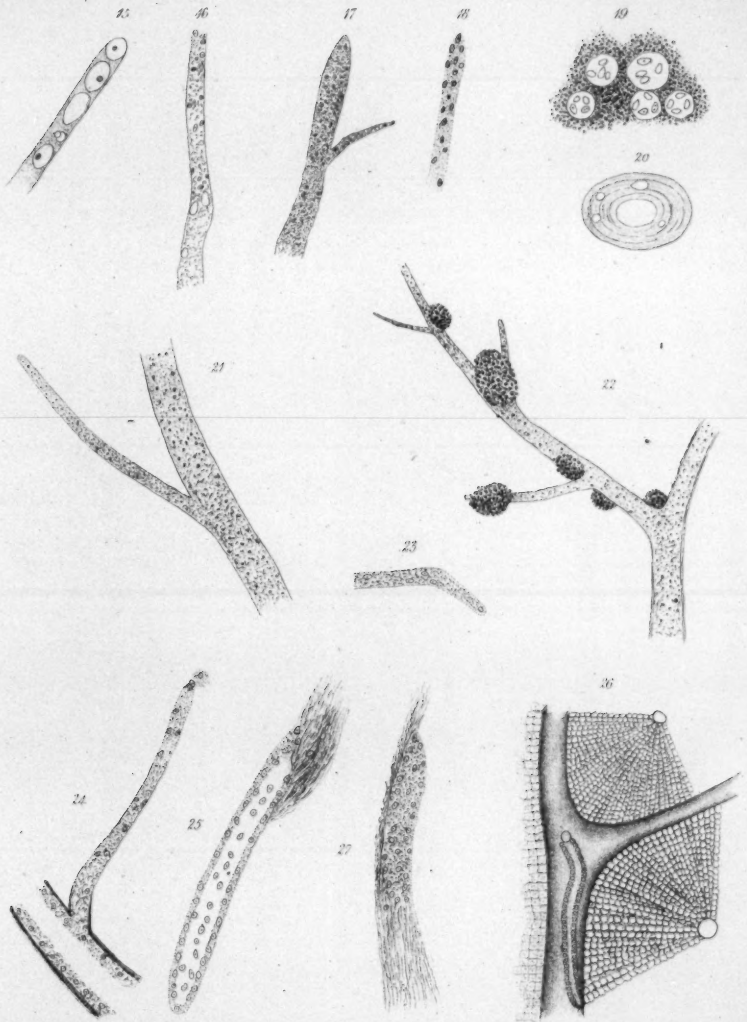

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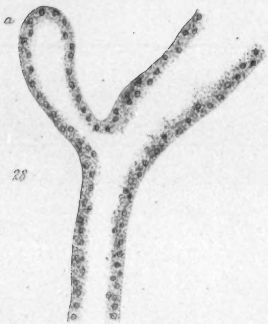

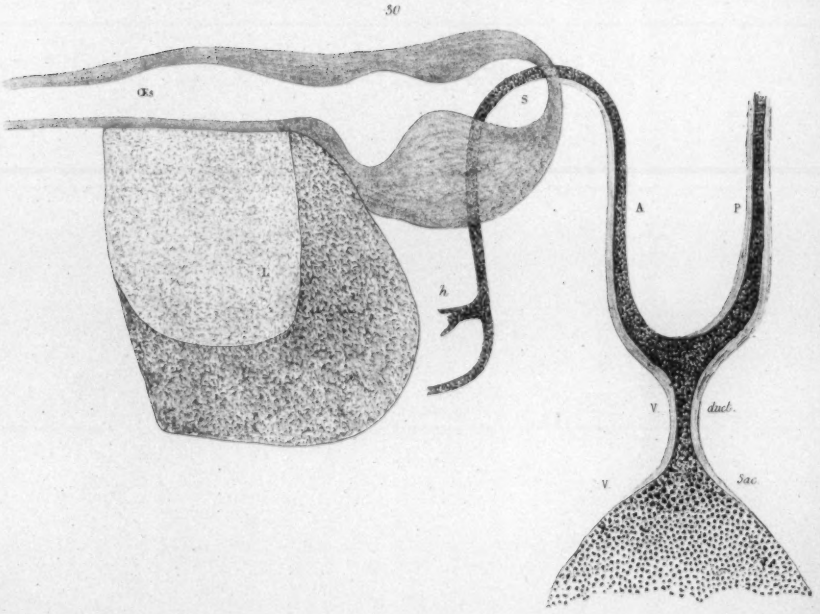

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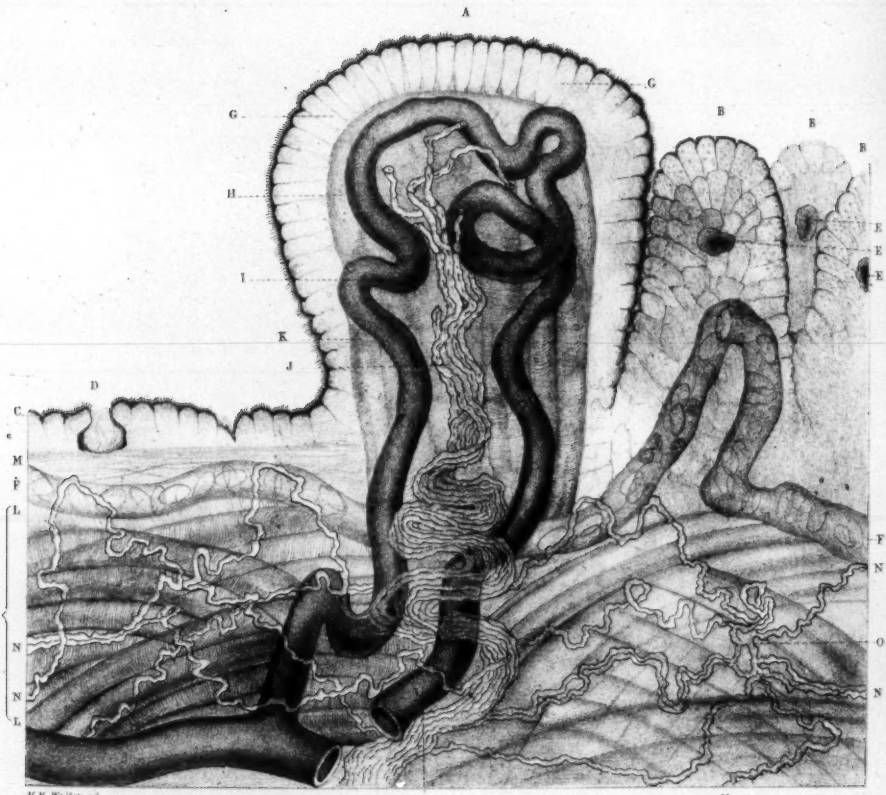

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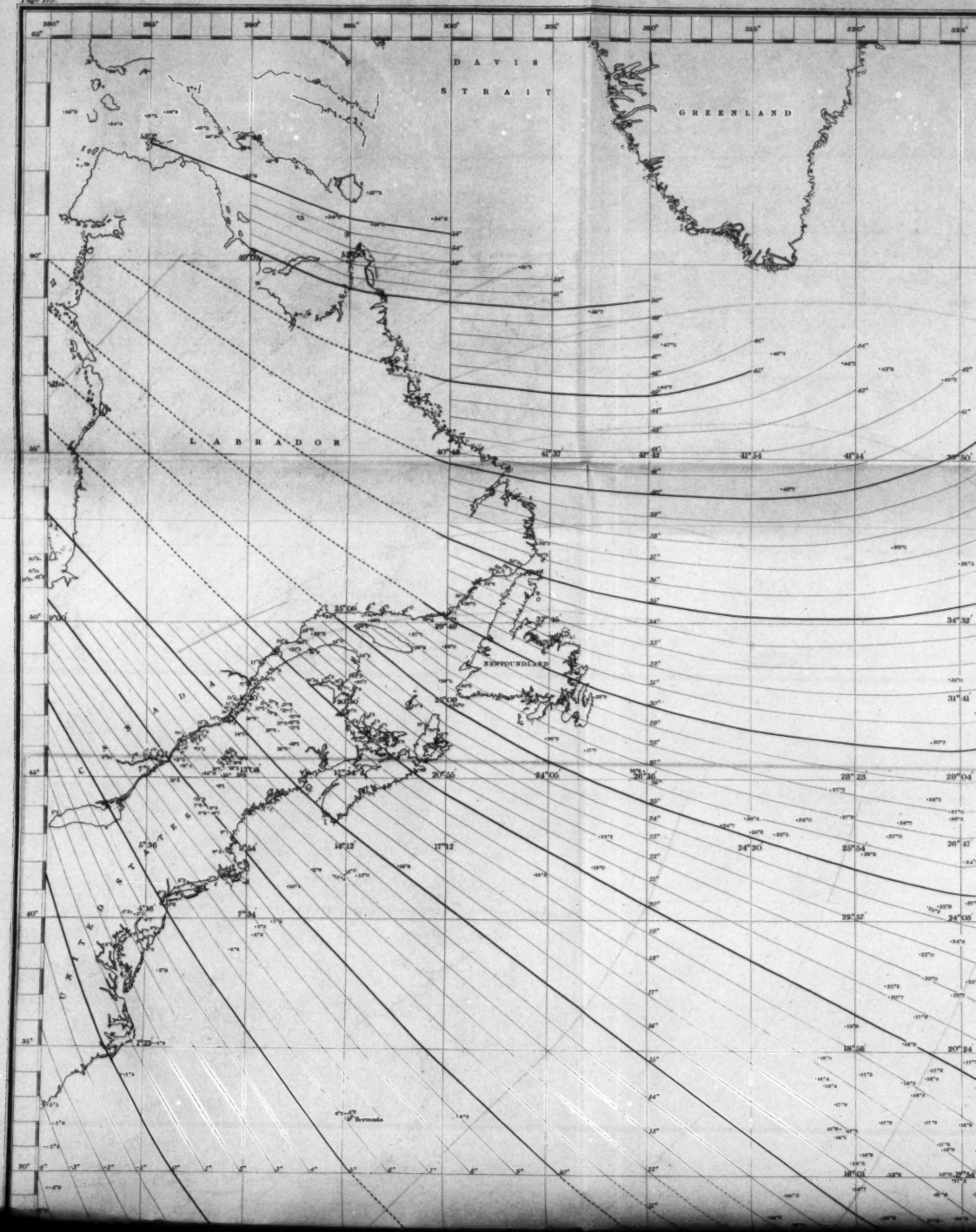
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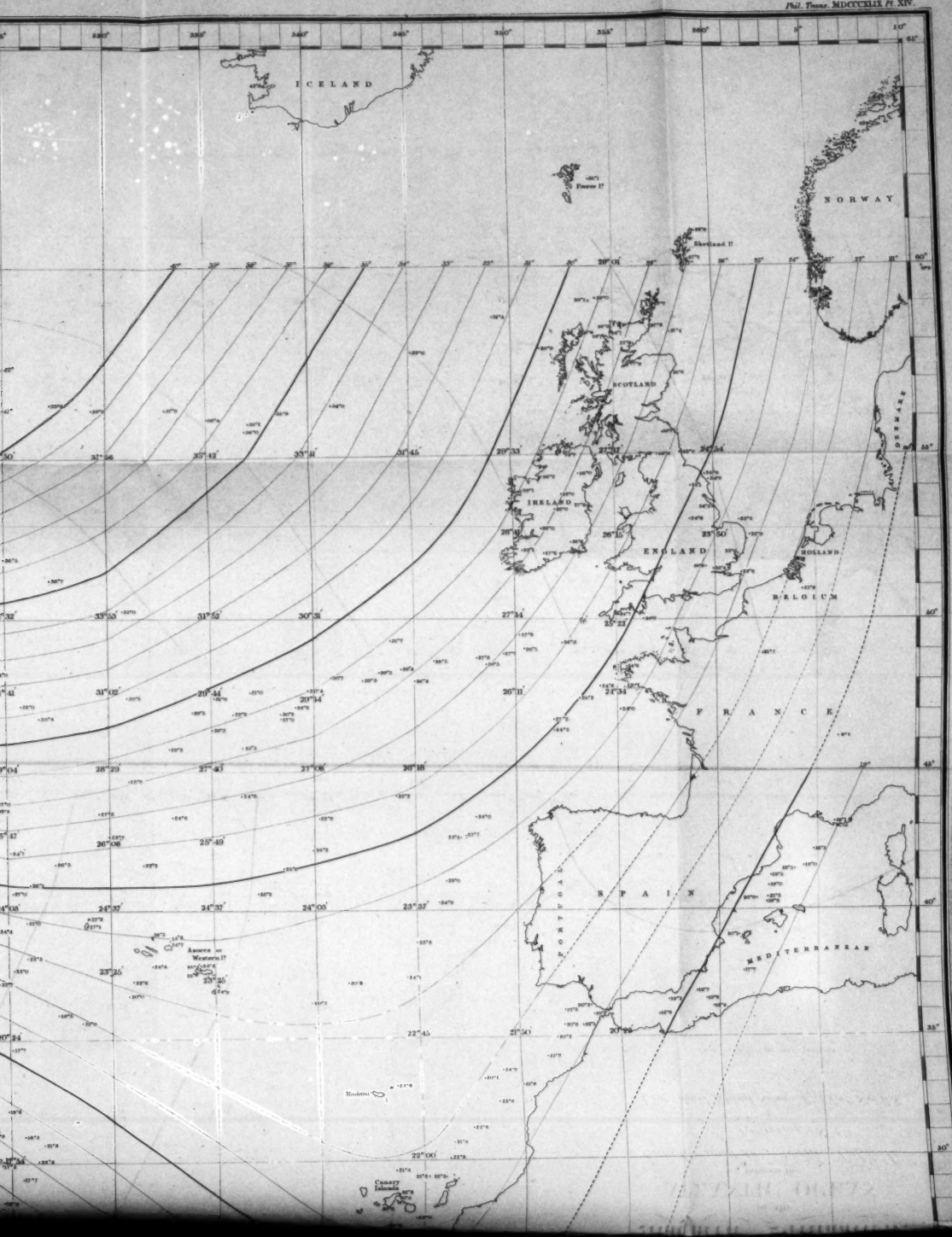
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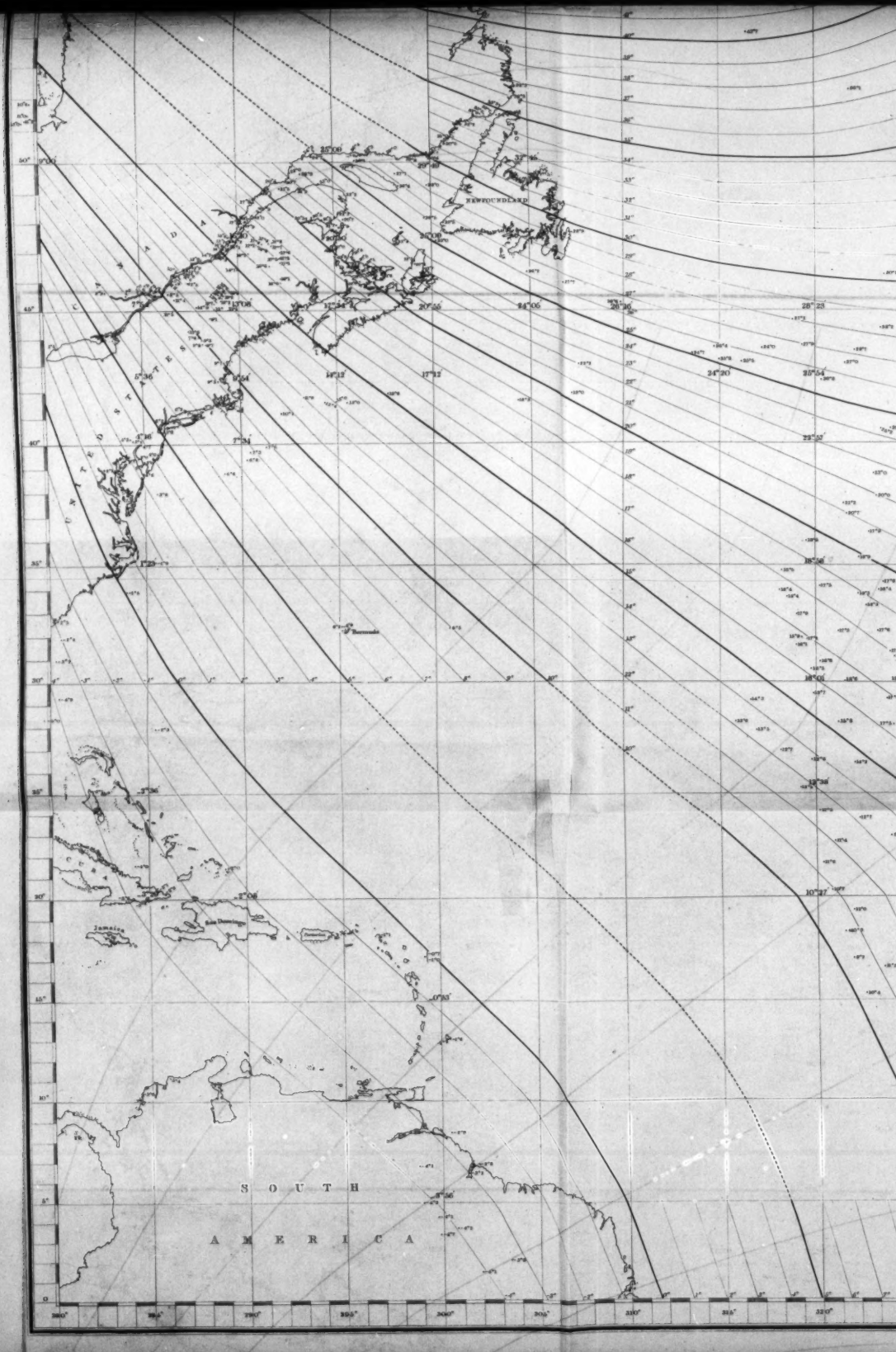
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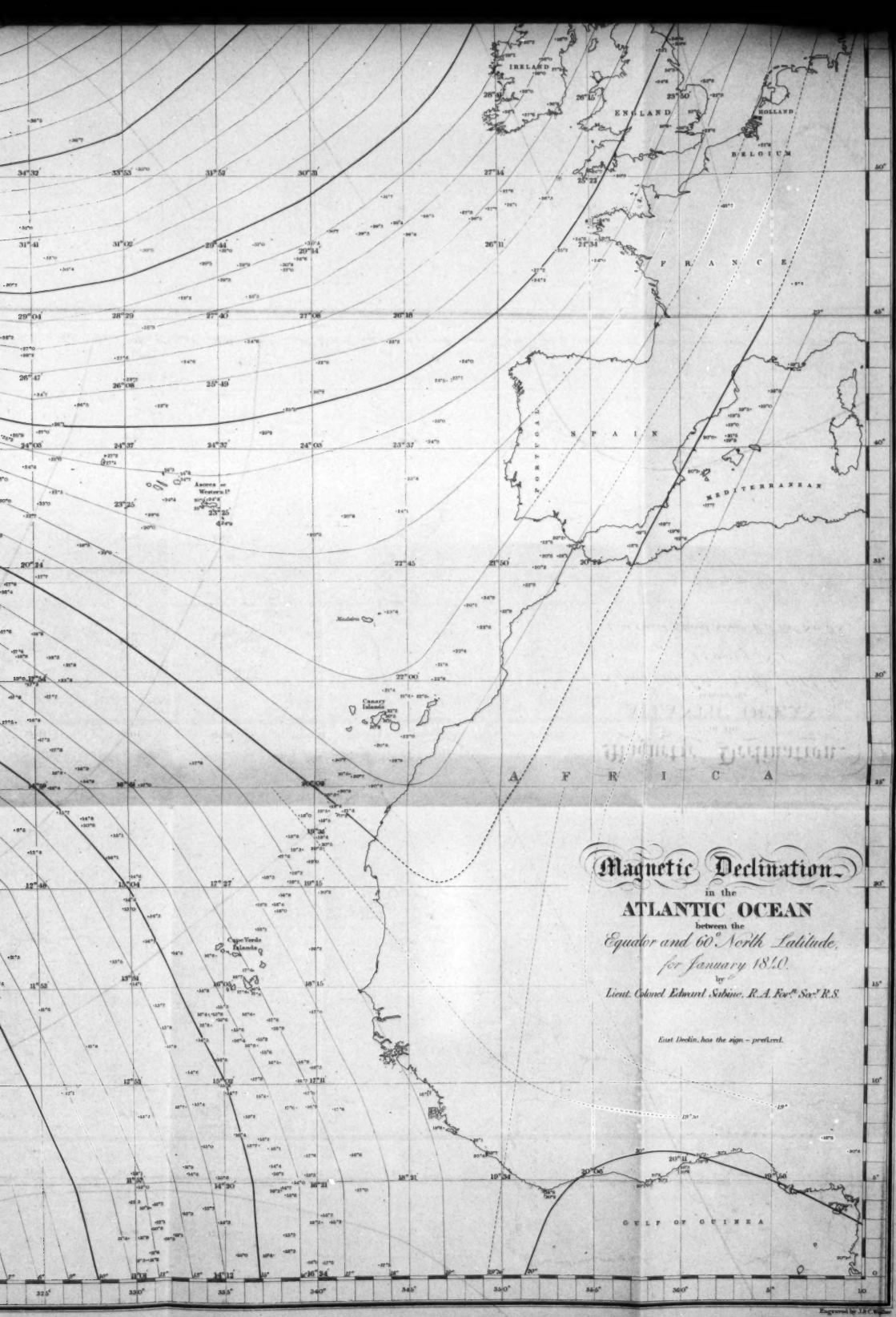


Magnetic Declination

in the

ATLANTIC OCEAN

between the

Equator and 60° North Latitude,

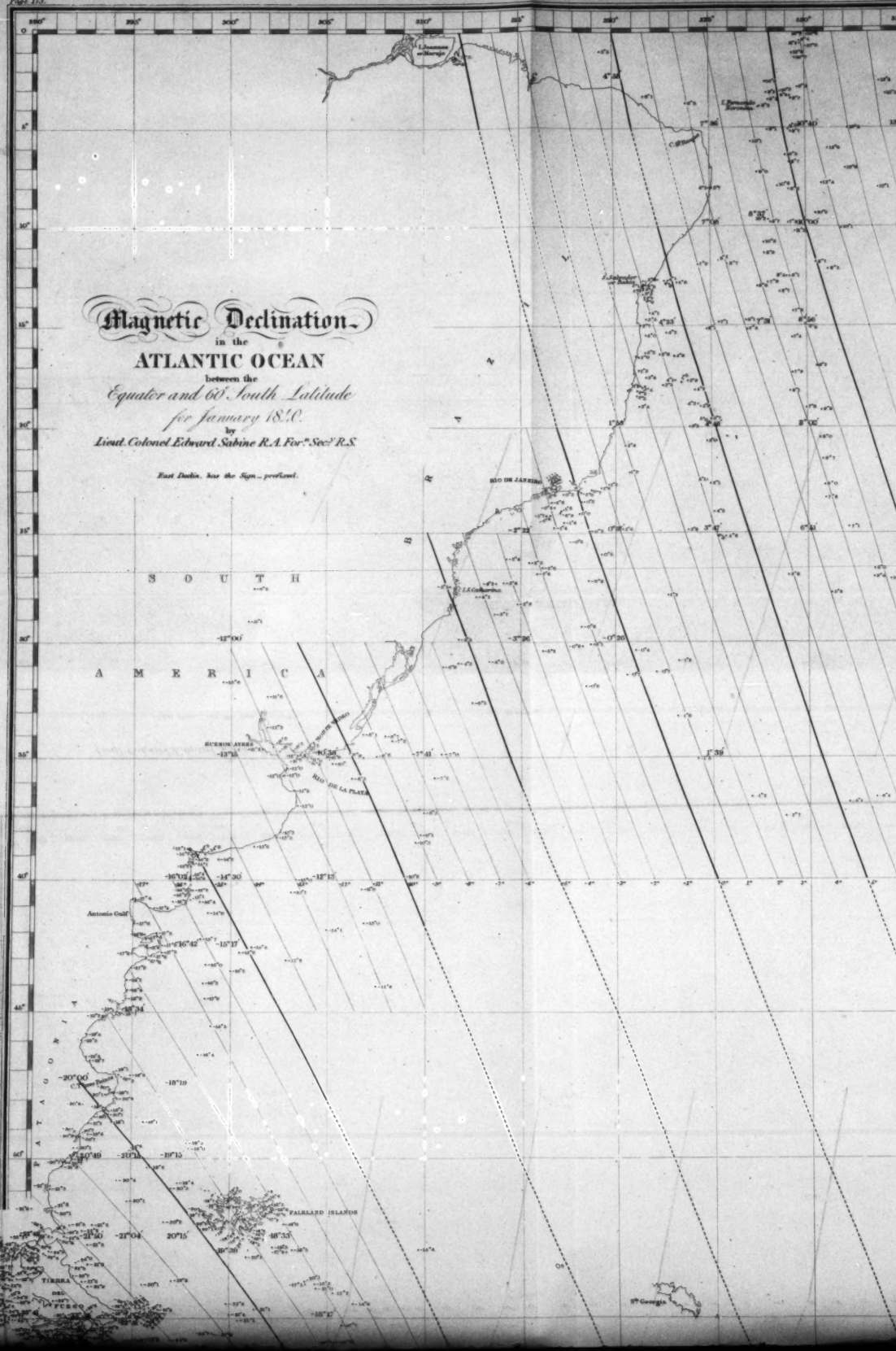
for January 1840.

by

Lieut. Colonel Edward Sabine, R.A. For.Sec.R.S.

East Declin. has the sign – prefixed.

Engraved by J.& C. Walker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St Georgia
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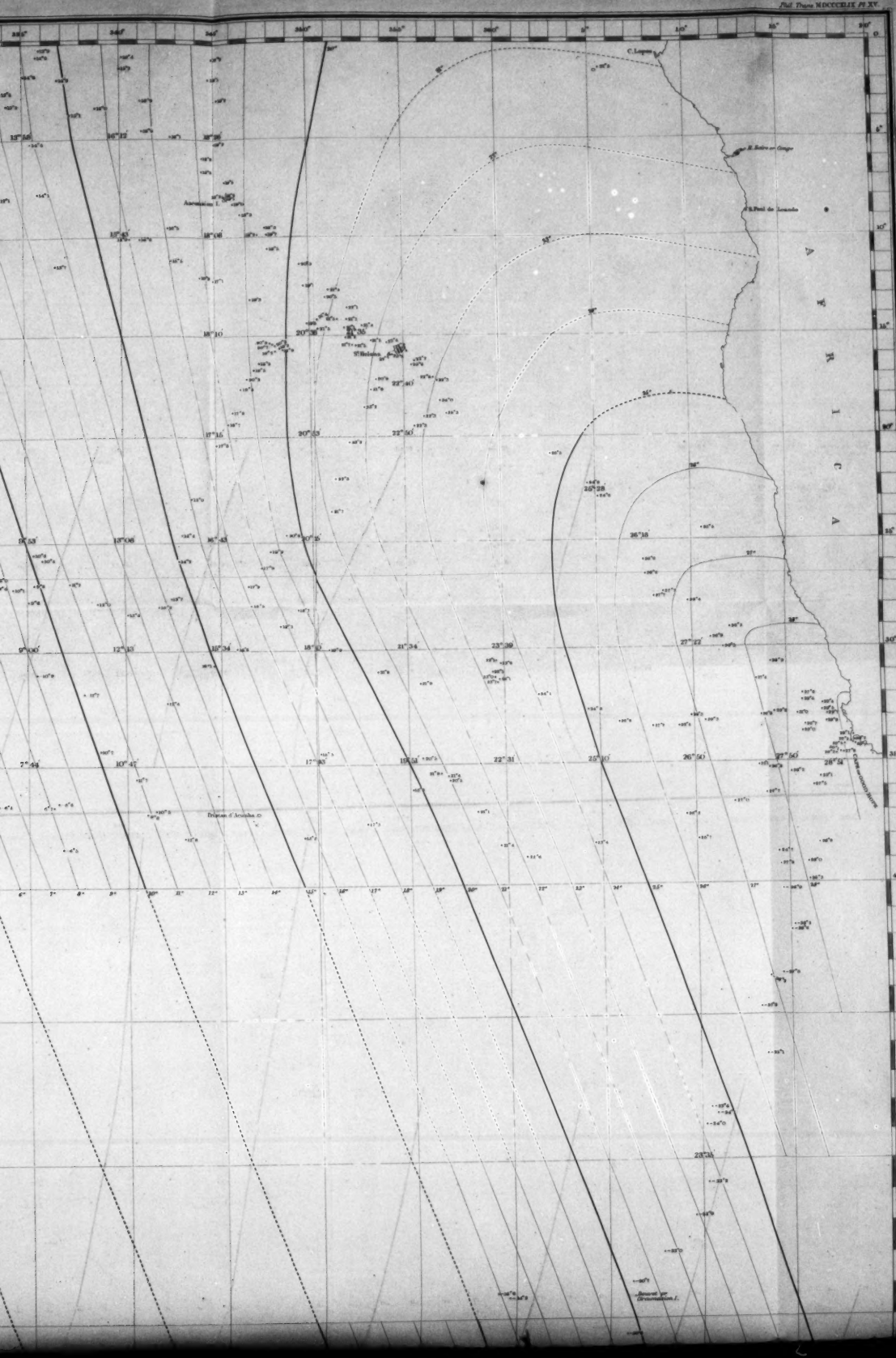
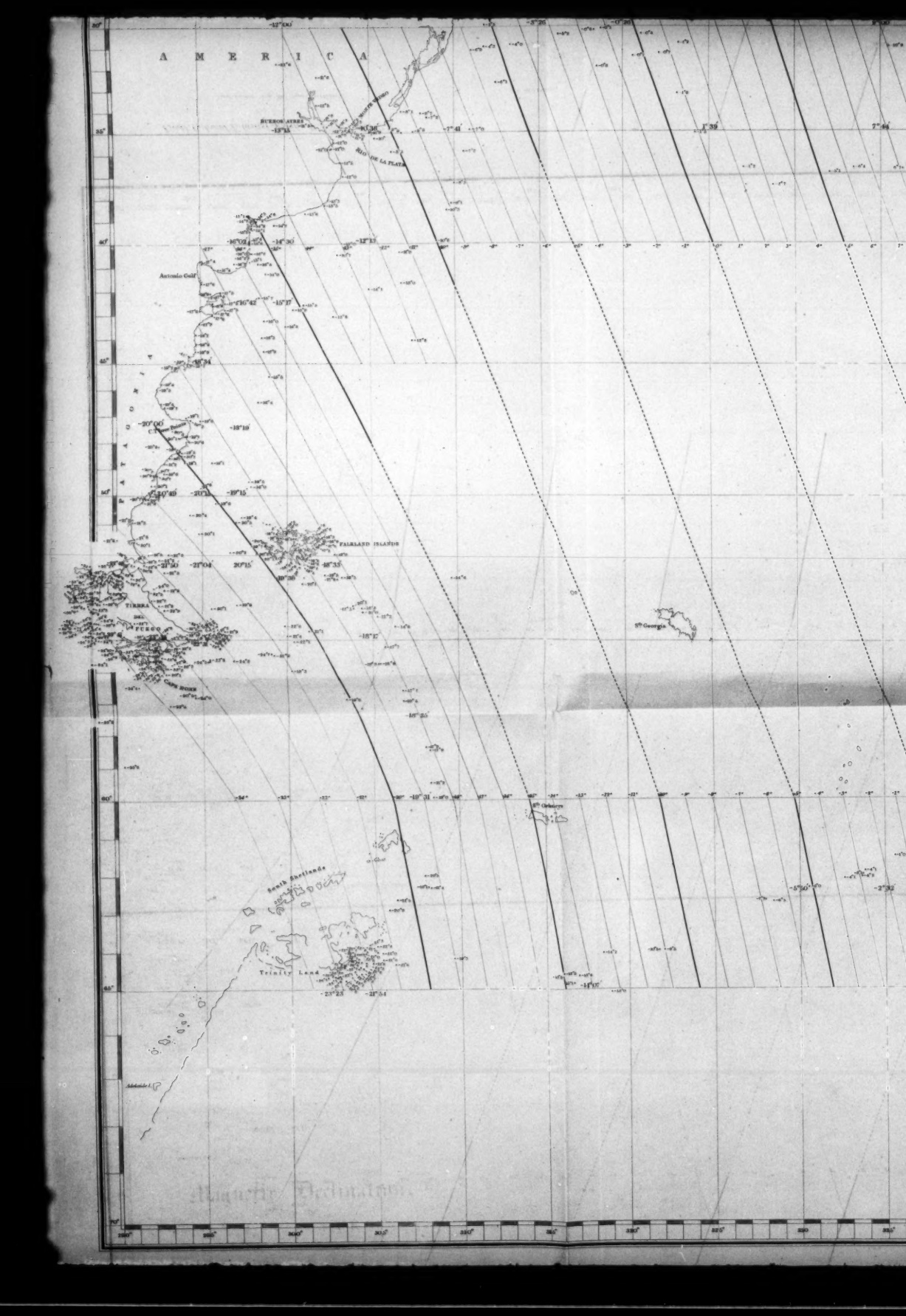
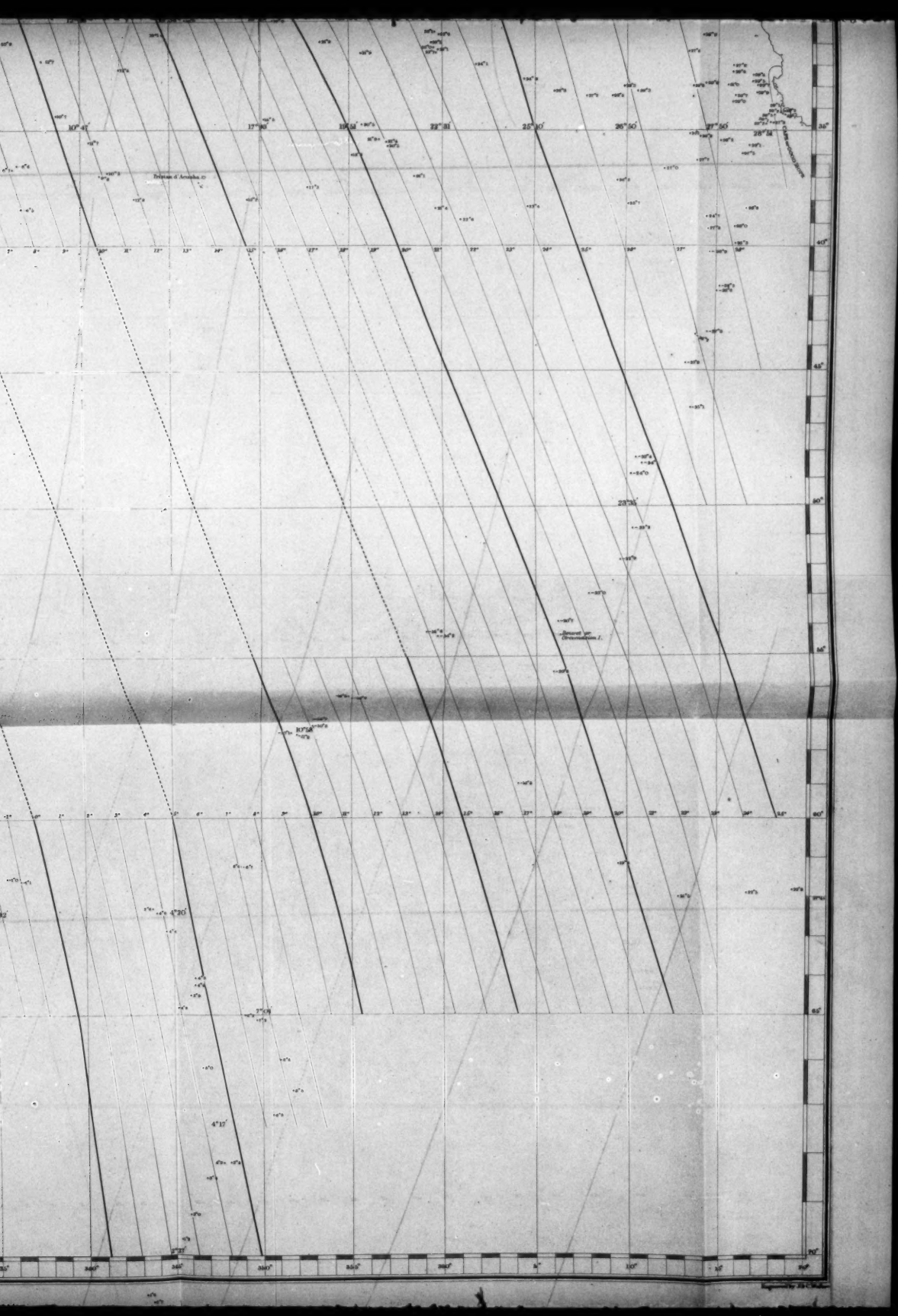
BUENOS AYRES
RIO DE LA PLATA
Antonio Gulf
C.t Blanco
C.t Corrientes
C.t Virgins
C.t Horn
Staaten Land
Desmochados
-12°00'
-14°30'
-16°00'
-18°15'
-20°00'
-21°04'
-19°15'
-20°15'
-18°33'
-18°42'
-15°17'
-12°15'
-7°41'
-7°39'
-0°20'
-2°26'
-3°23'
-7°28'
-8°26'
-8°38'
-8°33'
-8°00'
-7°06'
-4°28'
-3°43'
-6°51'

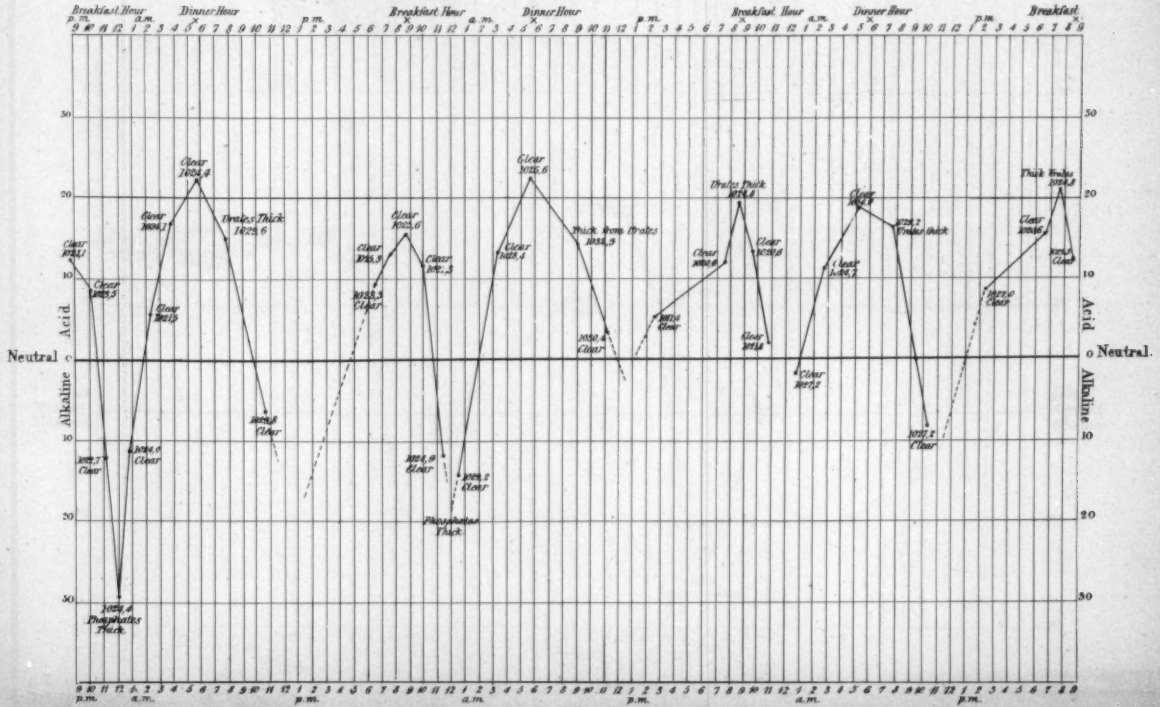

AFRICA
C. Lopez
S. Paul de Loando
St. Helena
Ascension I.
Fernan d'Acunha
Observed per Circumnavn. f.


A M E R I C A
BUENOS AYRES
RIO DE LA PLATA
Antonio Gulf
FALKLAND ISLANDS
TIERRA
DEL
FUEGO
Cape Horn
S. Georgia
S. Orkneys
South Shetlands
Trinity Land
Adelaide I.

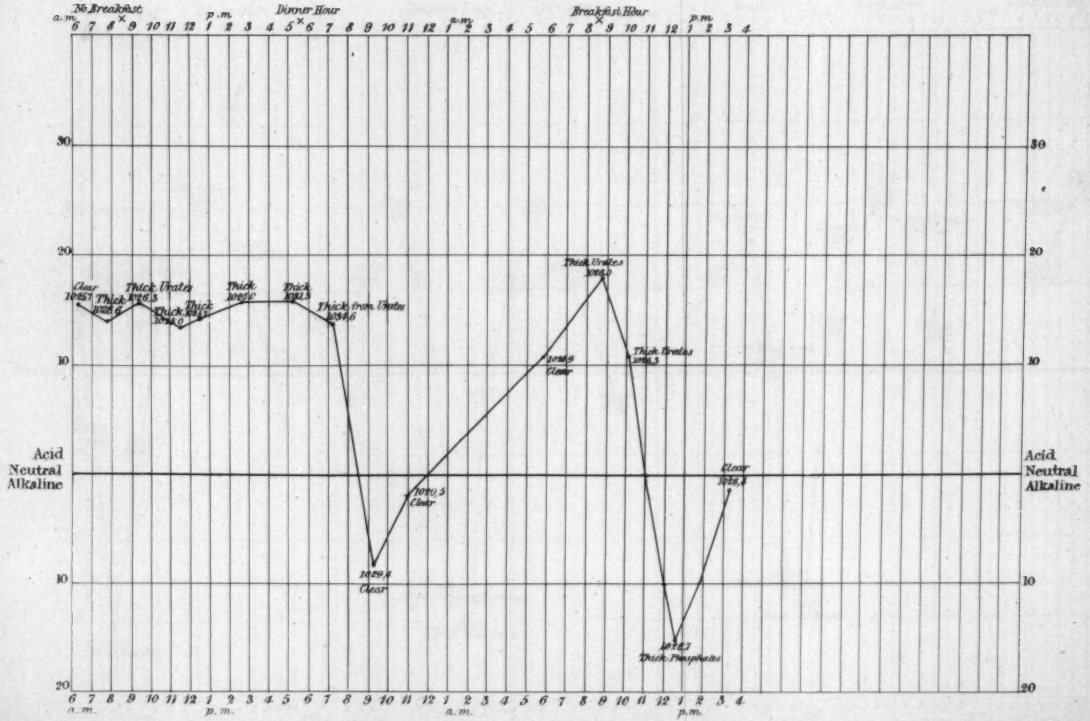


The Variations of Acidity during Seventy two hours when a Mixed diet was taken

Each degree of Alkalescence or Acidity equals the twelfth of a grain of Carbonate of Soda (dry & pure)

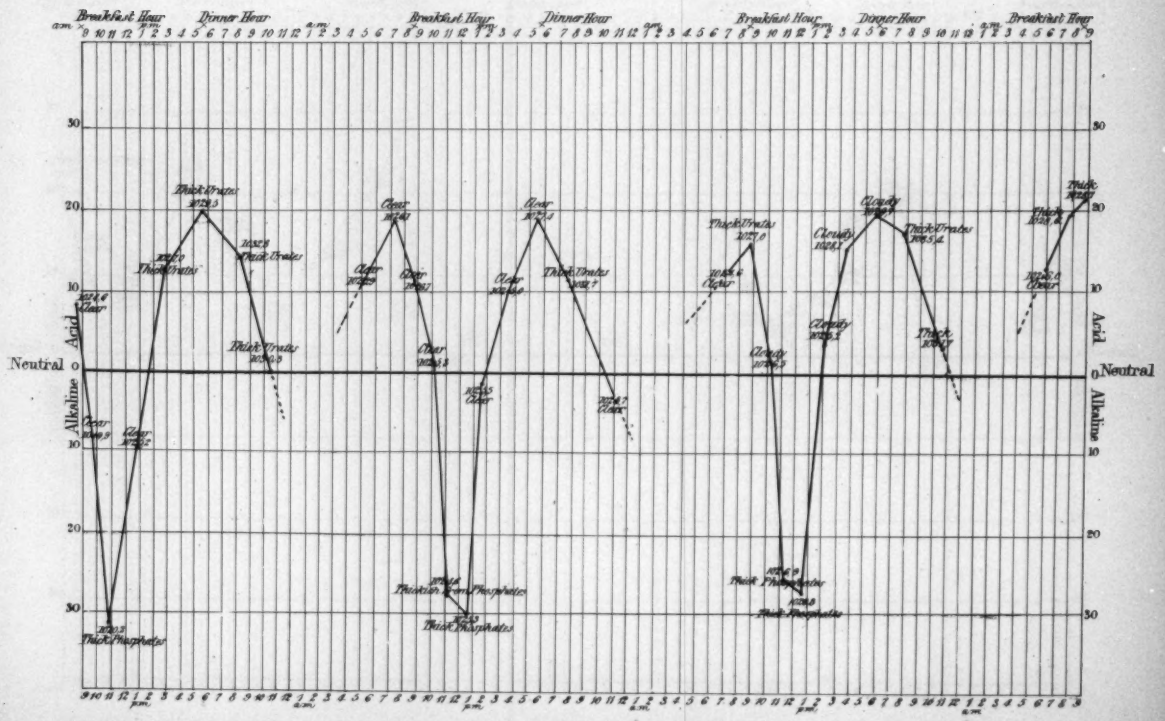

Breakfast Hour
Dinner Hour
Breakfast Hour
Dinner Hour
Breakfast Hour
Dinner Hour
Breakfast
Neutral
Acid
Alkaline
Neutral
Acid
Alkaline
Clear 1024.4 Phosphates Thick.
Phosphates Thick
Urates Thick 1028.6
Urates Thick 1028.4
Urates Thick 1028.7
Thick Brick Urates 1033.9
Thick Brick 1033.8
Clear 1028.7
Clear 1027.9
Clear 1027.2
Clear 1027.1
Clear 1025.5
Clear 1024.8
Clear 1024.1
Clear 1026.5
Clear 1025.8
Clear 1025.6
Clear 1025.4
Clear 1026.6
Clear 1026.4
Clear 1026.8
Clear 1026.7
Clear 1026.6
Clear 1027.0
Clear 1026.4
Clear 1026.8
Clear 1027.1
Clear 1027.2
Clear 1027.7
Clear 1026.6
Clear 1026.5
Clear 1026.8
Clear 1027.1
Clear 1026.8
Clear 1026.7
Clear 1026.6
Clear 1026.4

Comparison of the Variations of the Acidity when no food was taken with the Variations when food was taken.



J. Basire, lith.

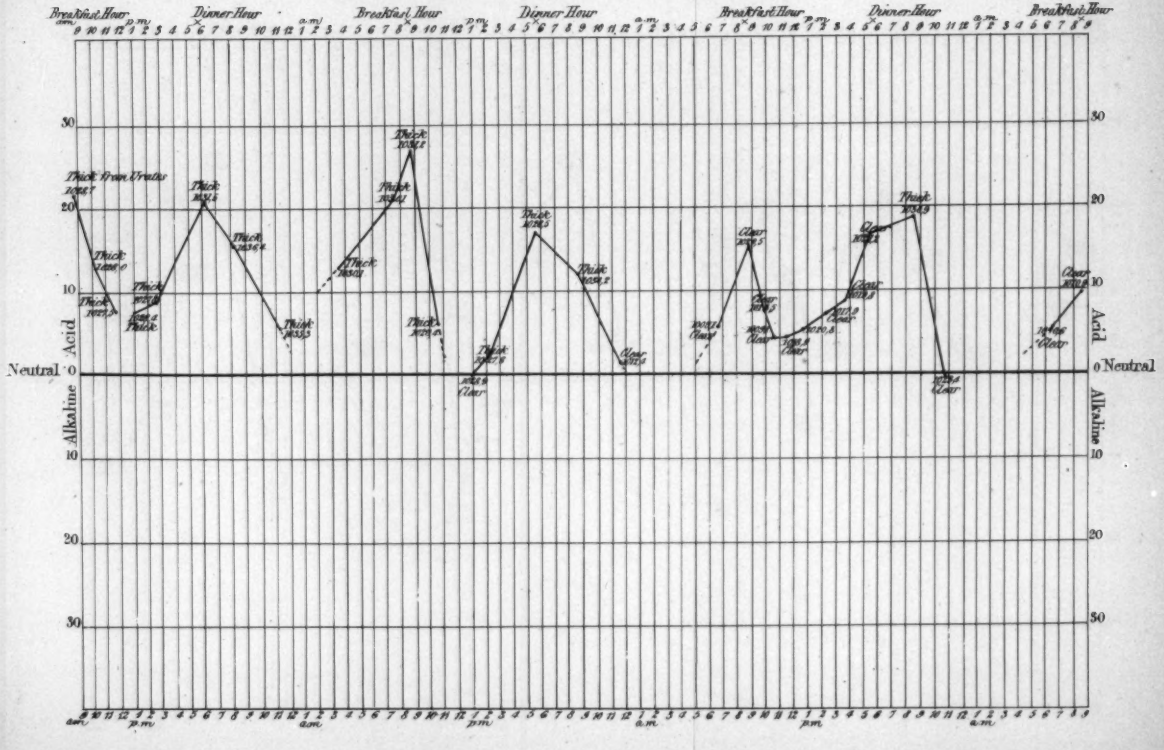
The Variations of the Acidity of the Urine during Seventy two hours, when Animal food only was taken.



J. Basire, lith.

Phil. Trans. MDCCCLIX. Plate XIX. p. 880.

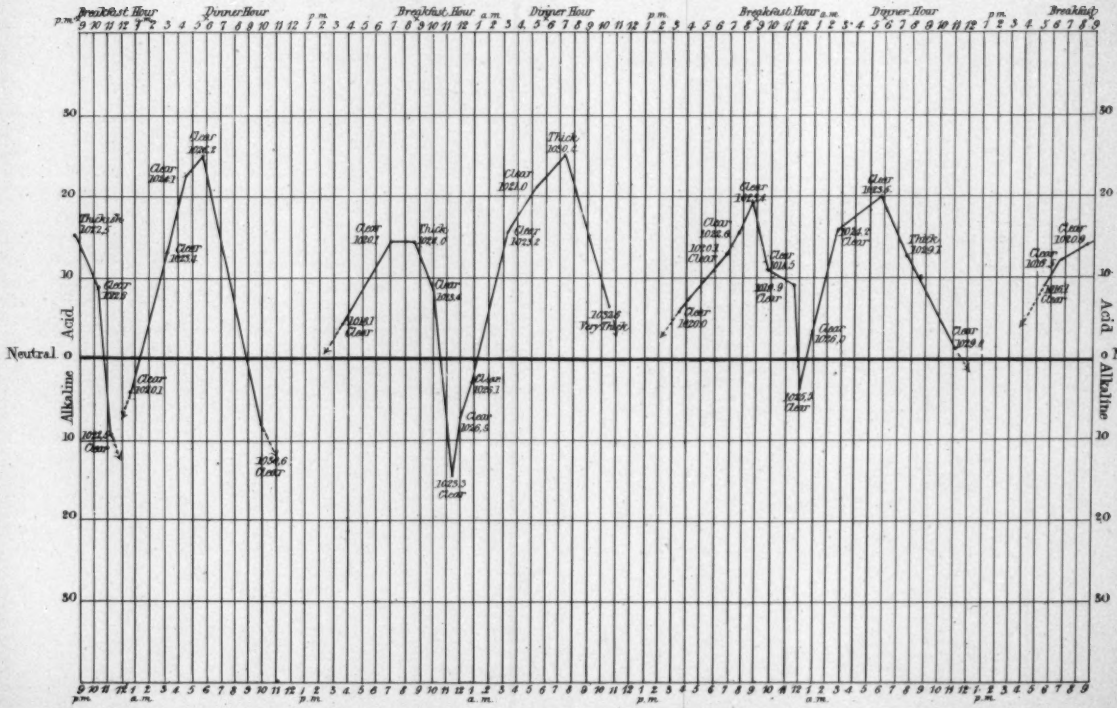
The Variations of the Acidity of the Urine during Seventy two hours when Vegetable food only was taken.



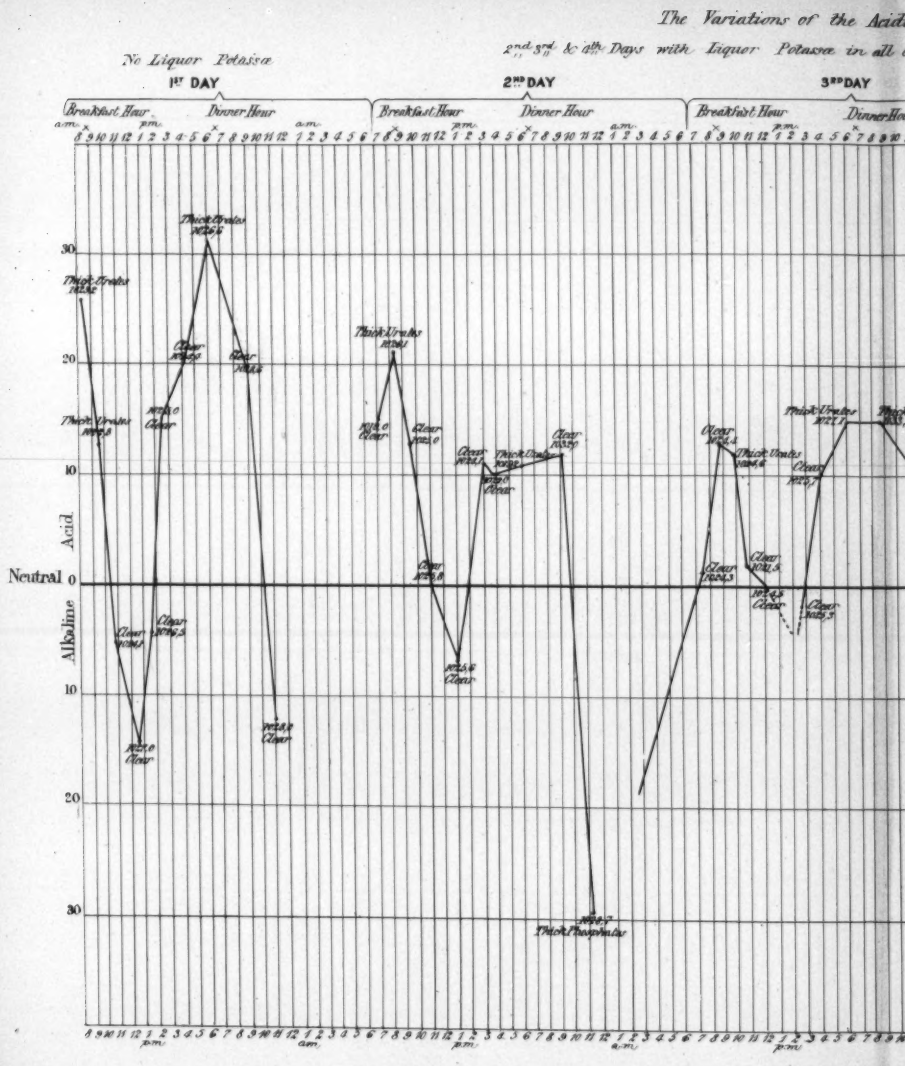
J. Basire, Sc.

The Variations of the Acidity of the Urine during seventy two hours,

during which nine drachms of dilute Sulphuric Acid were taken in distilled water.



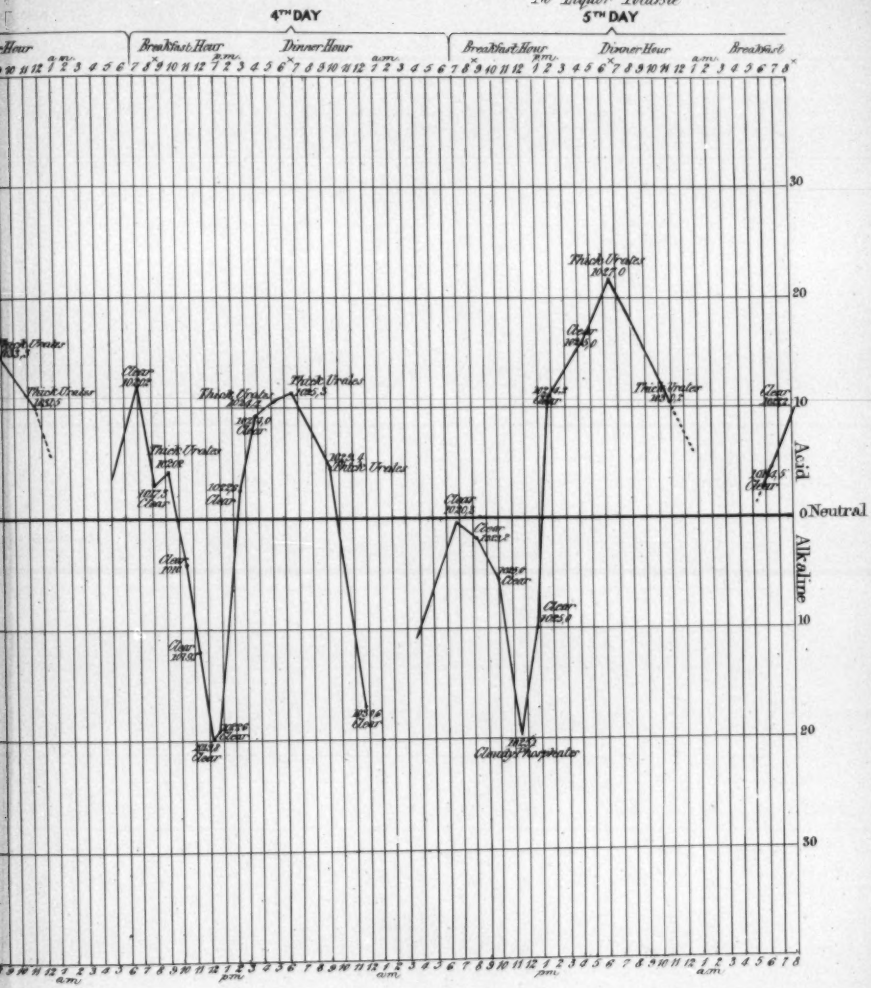
J. Basire lith.


The Variations of the Acid
No Liquor Potassæ
2nd, 3rd & 4th Days with Liquor Potassæ in all
1ST DAY
2ND DAY
3RD DAY
Breakfast Hour
Dinner Hour
Breakfast Hour
Dinner Hour
Breakfast Hour
Dinner Hour
Acid.
Neutral
Alkaline
Thick Urates
Clear
Thick Phosphates

idity of the Urine,

l one ounce specific gravity 1072.

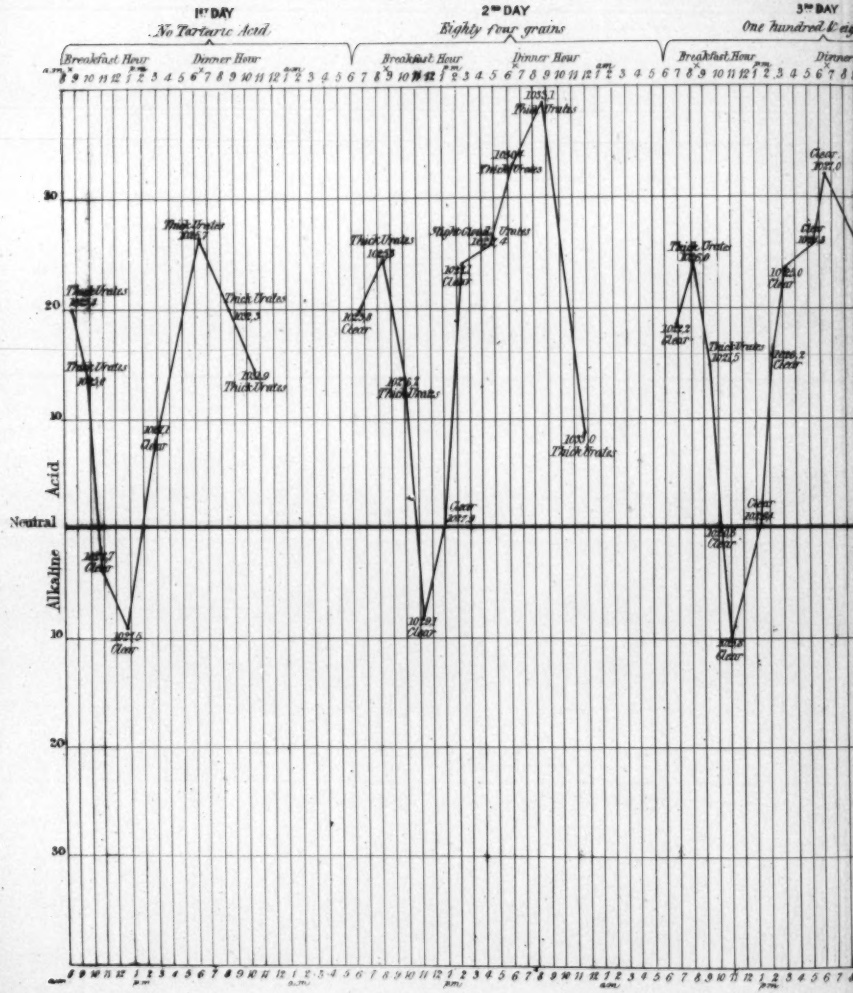
No Liquor Potassæ



J. Basire, Ldh.

The Variations of the

When Tartaric Acid



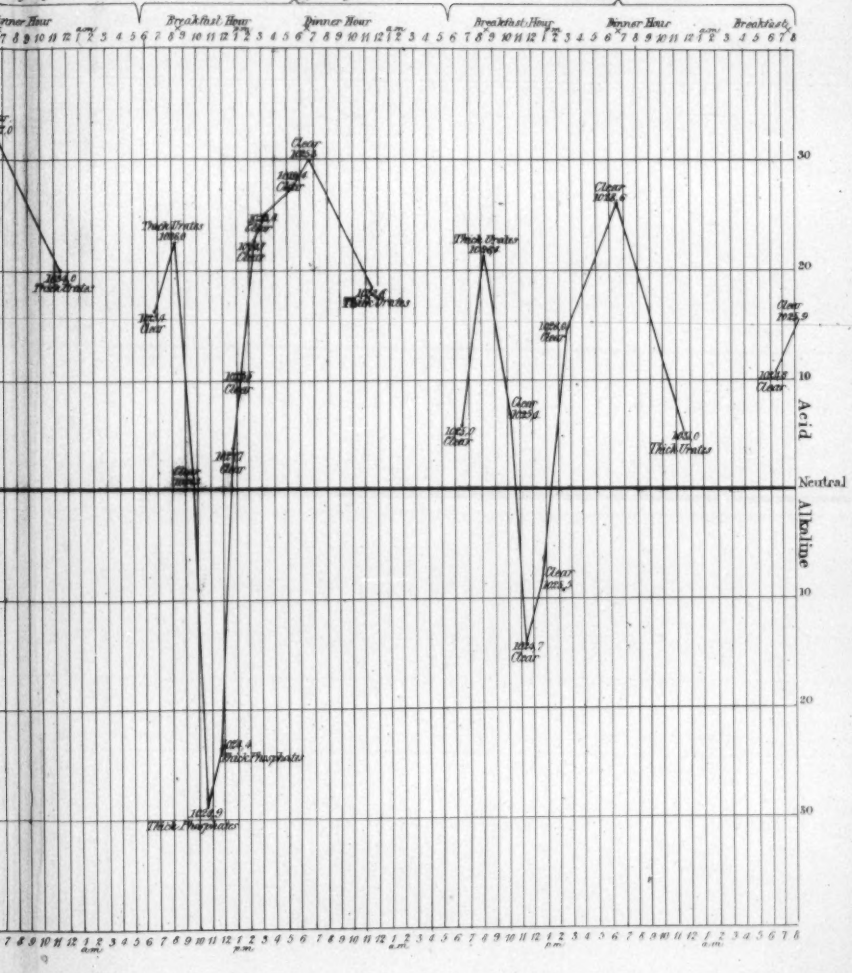
Acidity of the Urine

...d was taken.

...AY
...eight grains

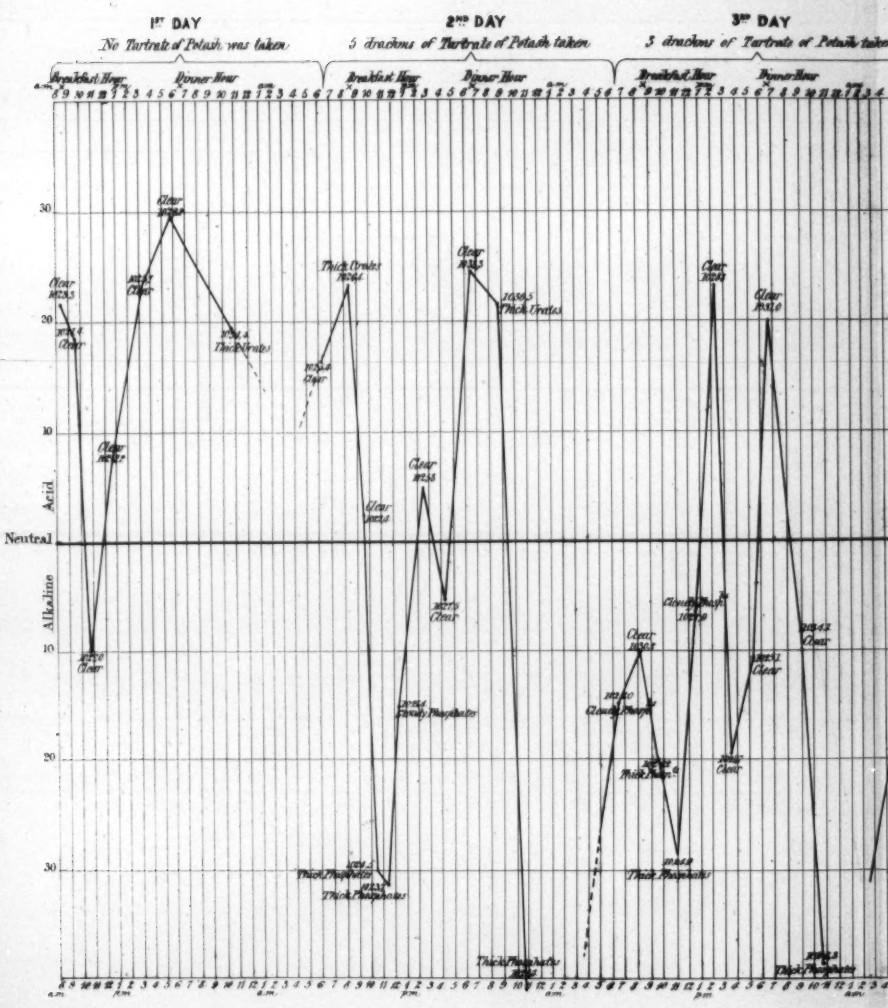
4TH DAY
One hundred & sixty five grains

5TH DAY
No Tartaric Acid was taken.

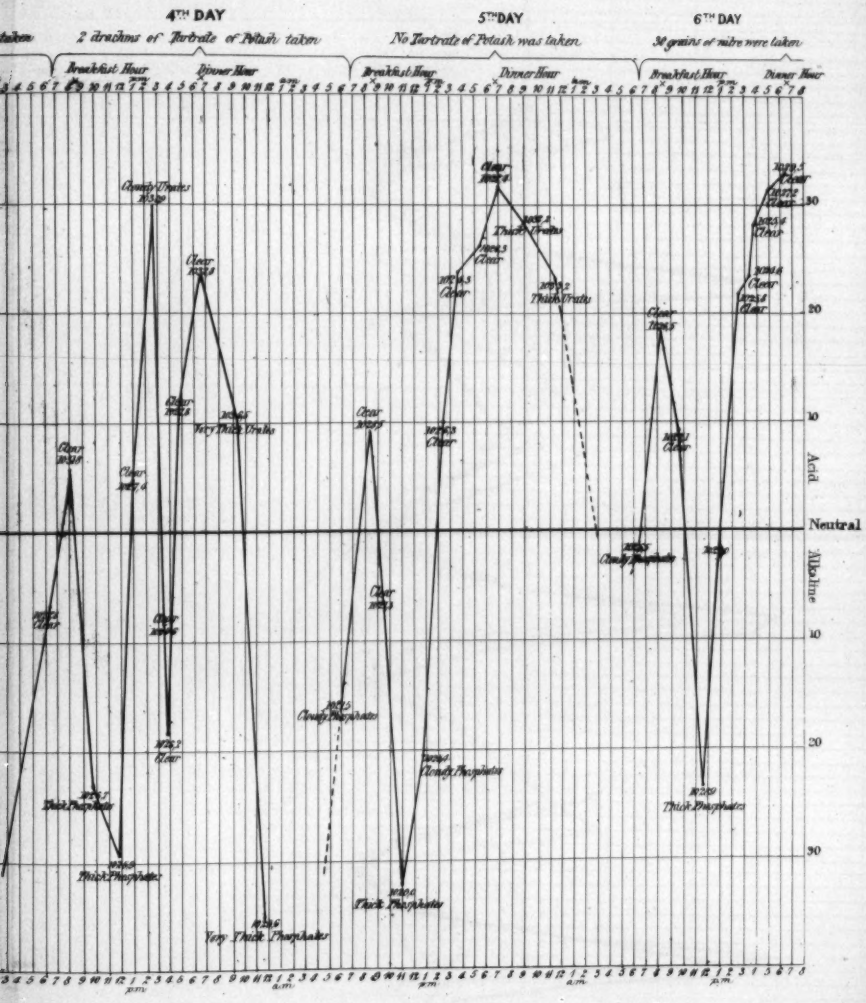


J. Basire Lith.

The Variations of the Acidity of the Ur



Urine with Tartrate of Potash.



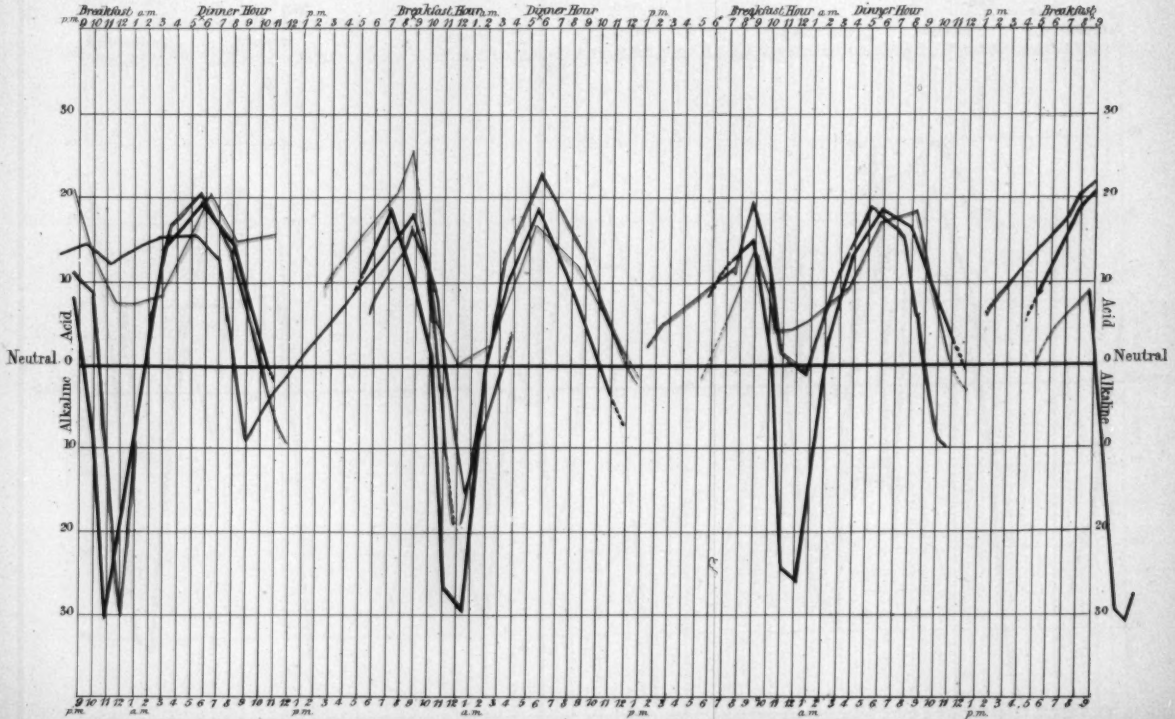
J. Basire, Junr.

The Variations of the Acidity of the Urine.

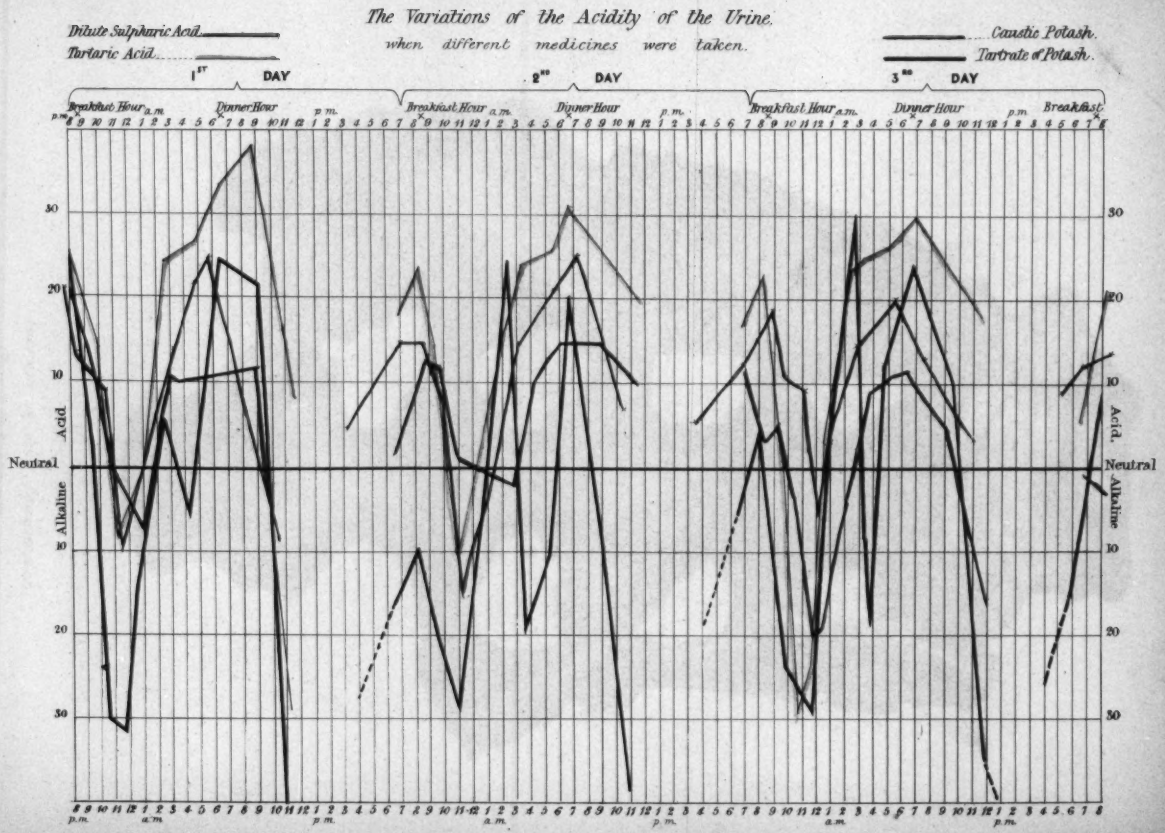
Mixed Diet.
Vegetable Food.

Each degree of Acidity or Alkalescence equals $\frac{1}{10}$ of a grain of Carbonate of Soda.

Animal Food.
No Food until Dinner



J. Basire lith.



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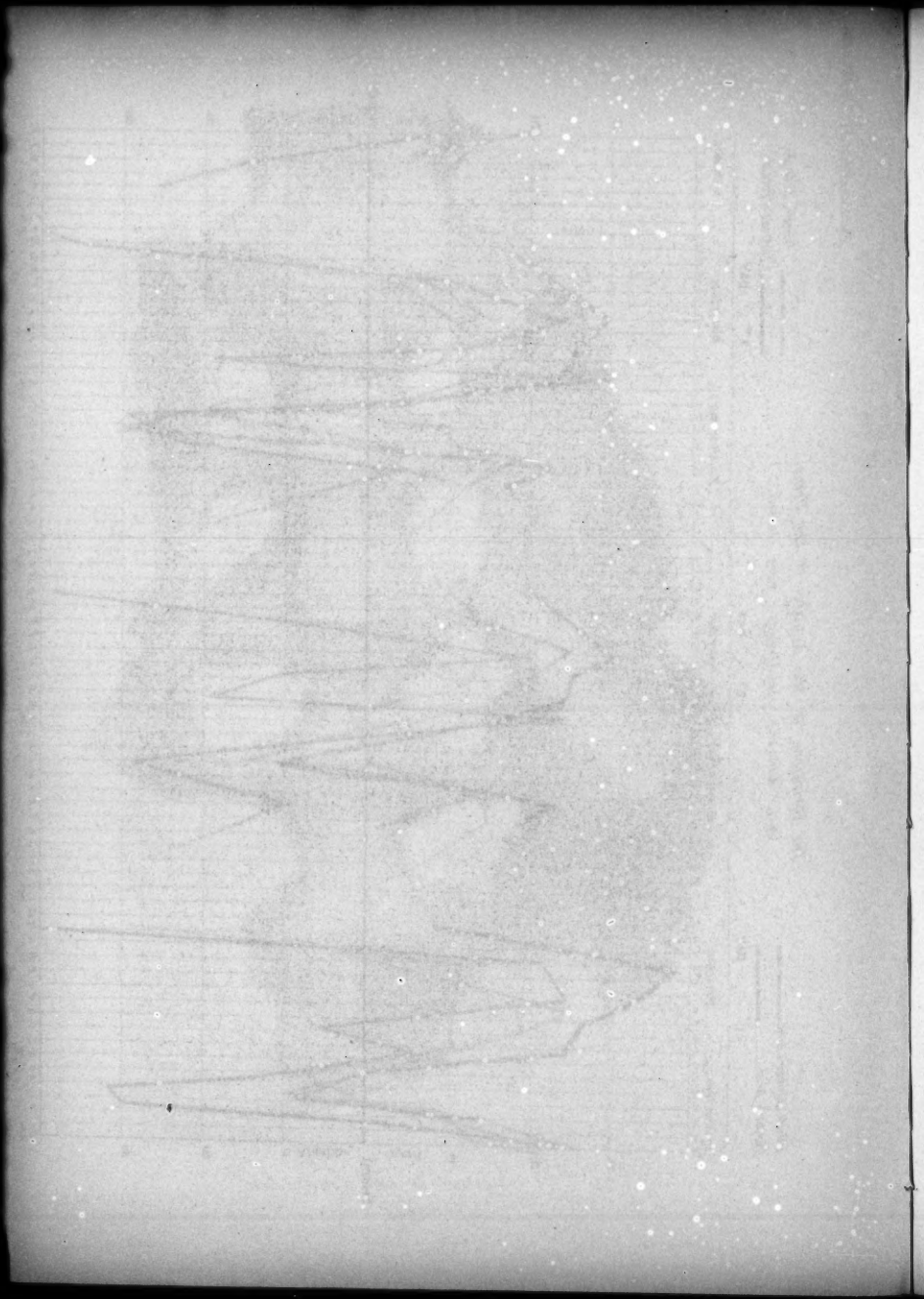
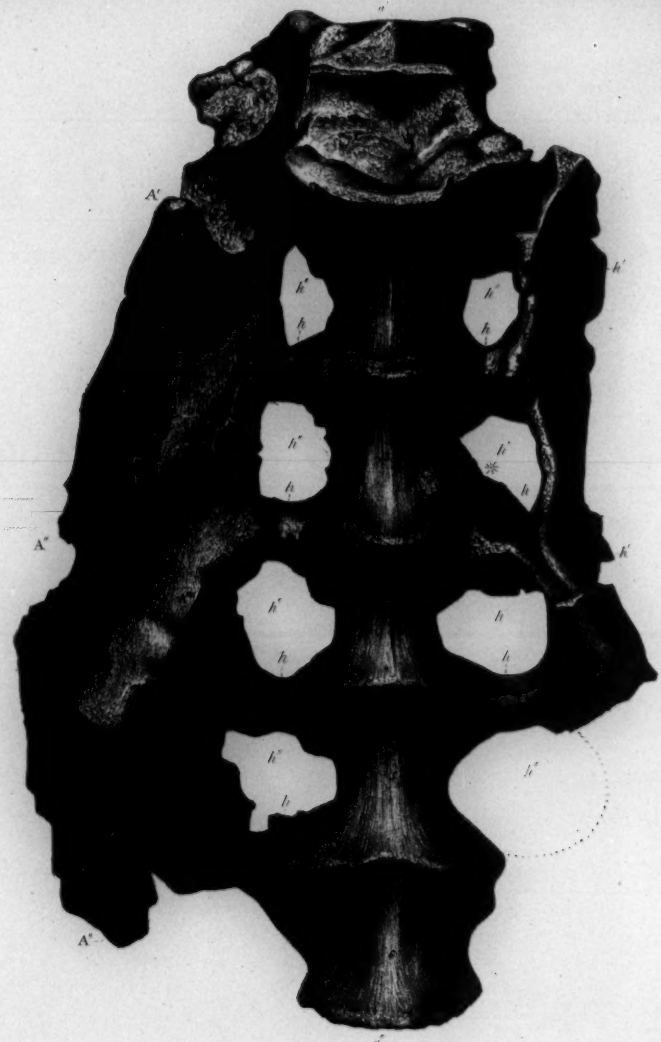




Sacrum of the Iguanodon.

(½ linear the natural size.)

Ward, del. Printed by J. Basire. J. Dinkel, lith.

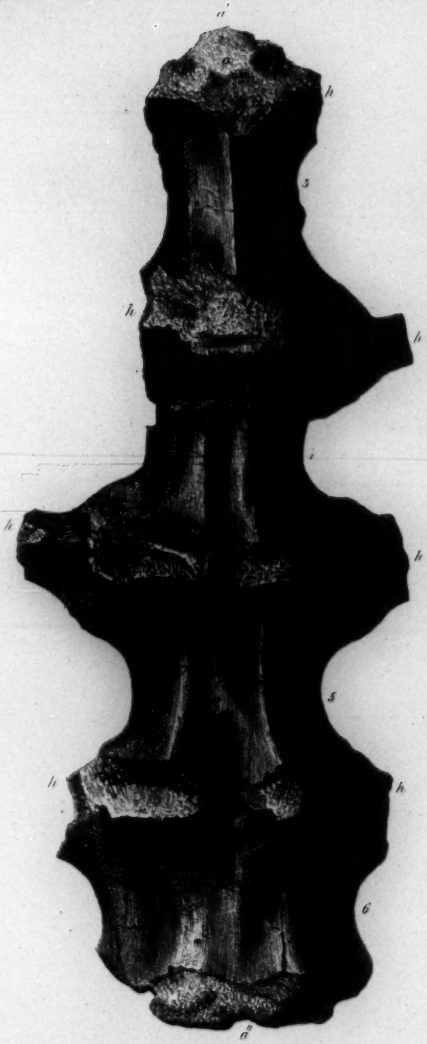
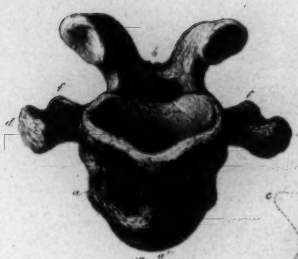


Fig. 2.
Visceral aspect.

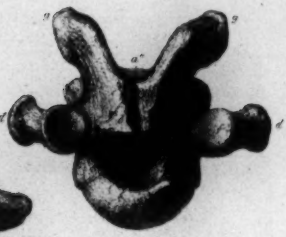
Fig. 3.
Lateral aspect.

Part of the Sacrum of the Hylæosaurus? nat. size.

Dinkel & West, del. Printed by J. Basire J. Dinkel, lith.



4a
¼ nat. size.



4b
¼ nat. size.

4c

5a
¼ nat. size.

5c

5b
¼ nat. size.

7a
¼ nat. size.

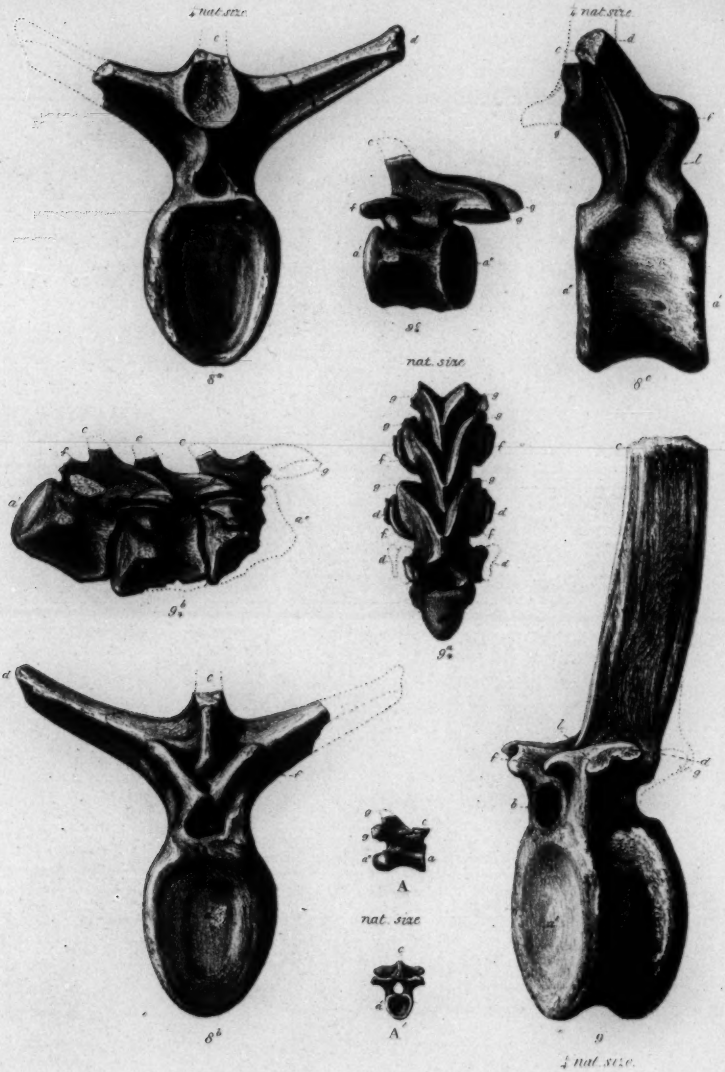
6
¼ nat. size.

7b
¼ nat. size.

Vertebræ of the Iguanodon.

Printed by J. Basire.

J. Dinkel, del. et lith.

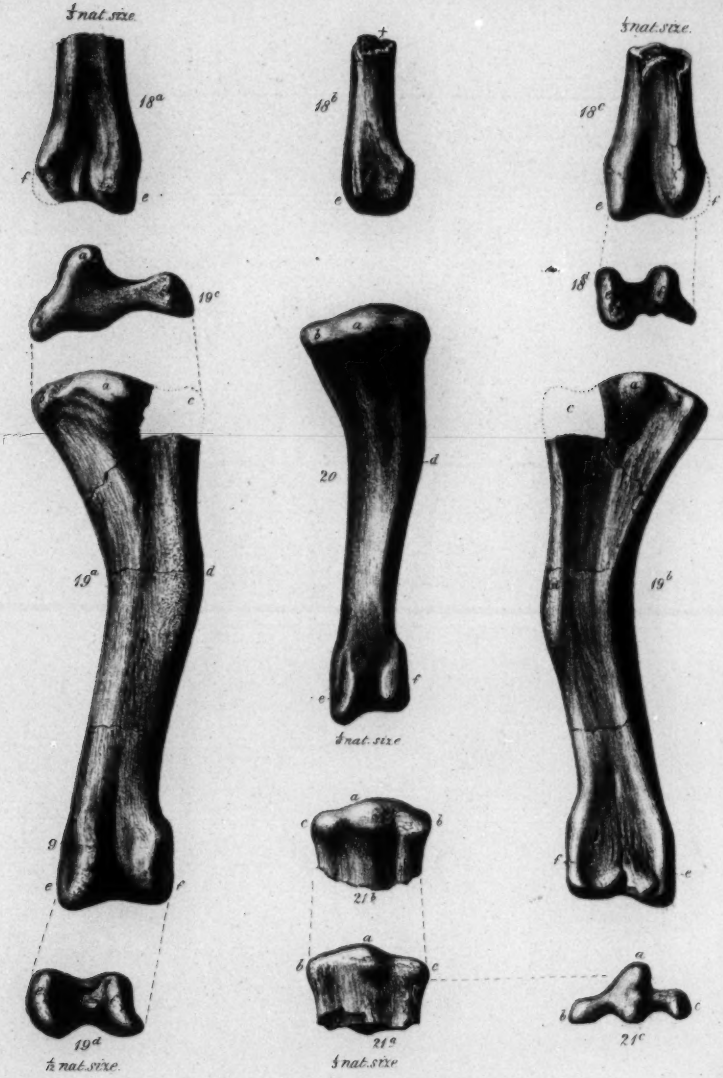


Vertebræ of the Iguanodon.

Drawn & Stoned by J. Scoutt del.
Printed by J. Basire.
J. Dinkel, lith.

Scapula, Coracoid and Vertebræ of the Iguanodon.

C. Scharf del. Printed by J. Basire. J. Dinkel. lith.

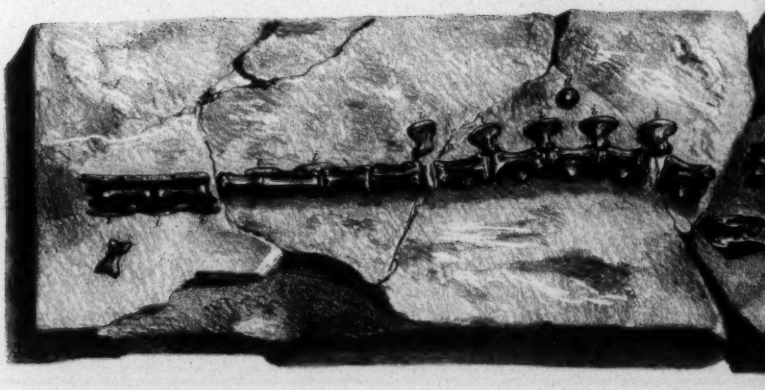


Humeri of the Iguanodon.

G. Scharf, del. Printed by J. Basire. J. Dinkel, lith.

22a

22b



22

24

22c

22

Posterior portion of the

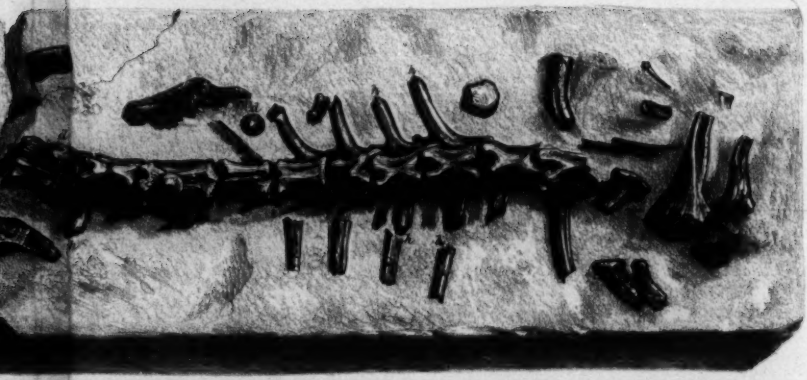
(½ nat

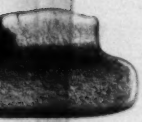
Printed by J. Basire

c. c. Chevronbones h. h.

22c

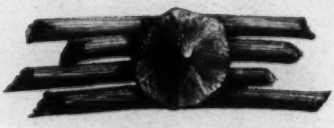
22d





22e

22g



23

...he Spinal Column of the Hylæosaurus.
...atural size.)

...h. Transverse processes. d. d. dermal bones.

J. Dinkel, del. et lith.

Fig. 1.

Fig. 3.

Fig. 4.

Fig. 2.

Fig. 5.

Fig. 7.

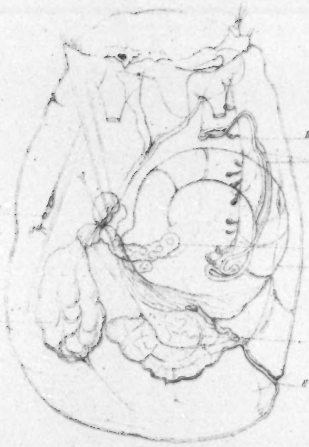


Fig. 6.

Fig. 8.

J. Basire Sculp.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 10.

Fig. 6.

Fig. 5.*

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 8.*

Fig. 11.

Fig. 13.

Fig. 12.

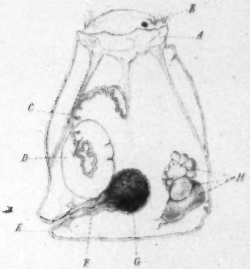
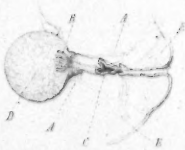


Fig. 14.



J. Basire, lith.

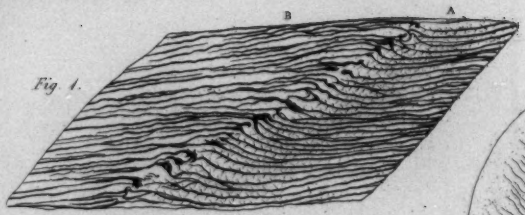


Fig. 1.

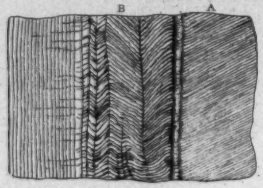


Fig. 2.

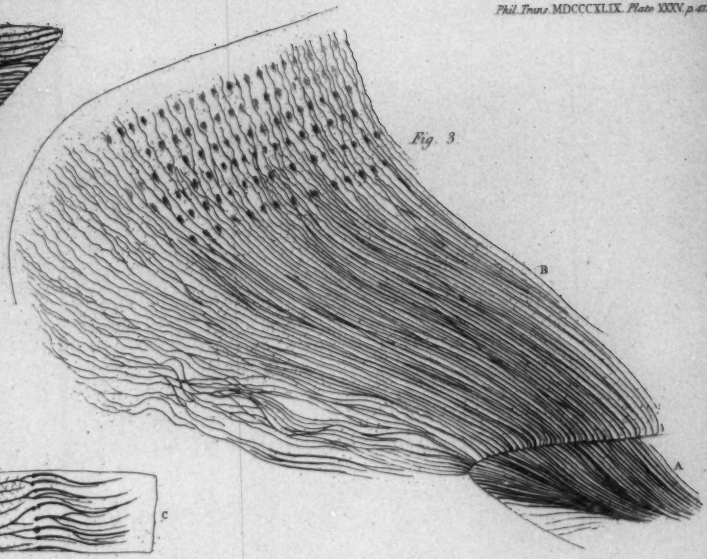


Fig. 3.

Fig. 4.

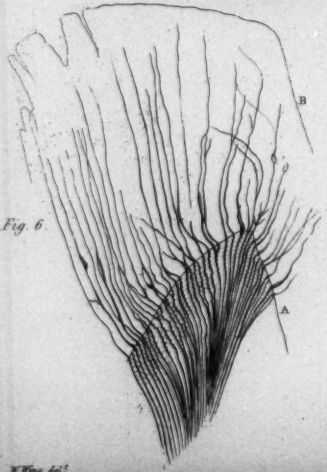
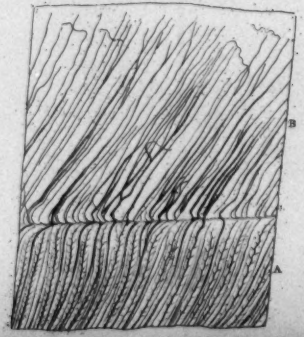


Fig. 6.



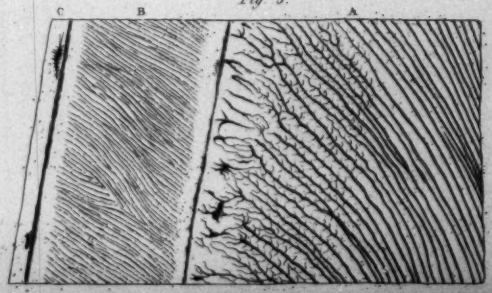


Fig. 5.

W. Wing. del.

J. Basire sc.

Fig. 7.

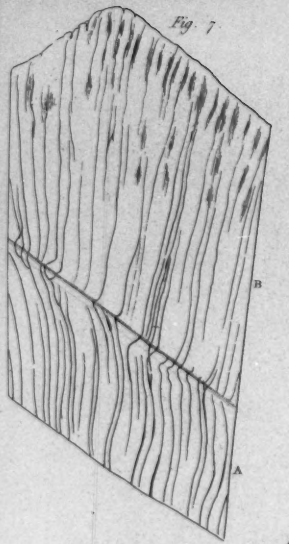


Fig. 8.

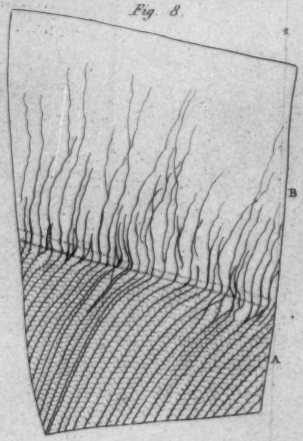


Fig. 9.

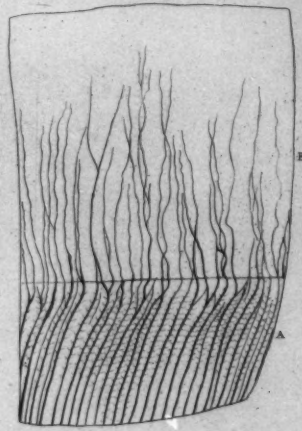


Fig. 10.

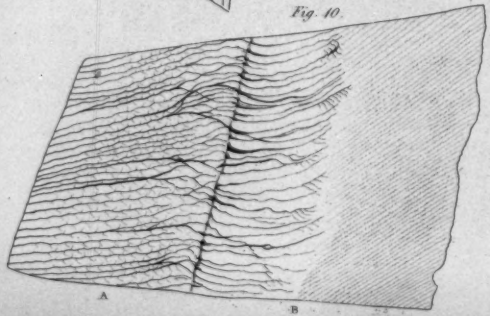


Fig. 11.

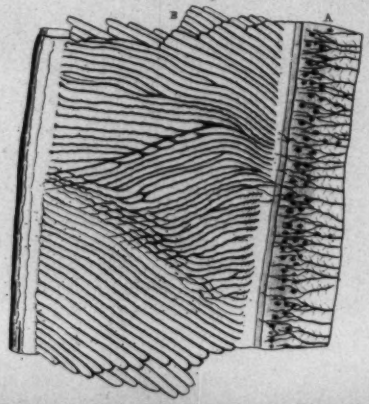
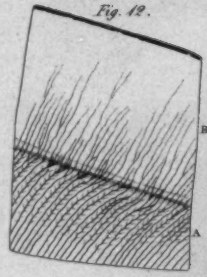


Fig. 12.



W Wing. del.

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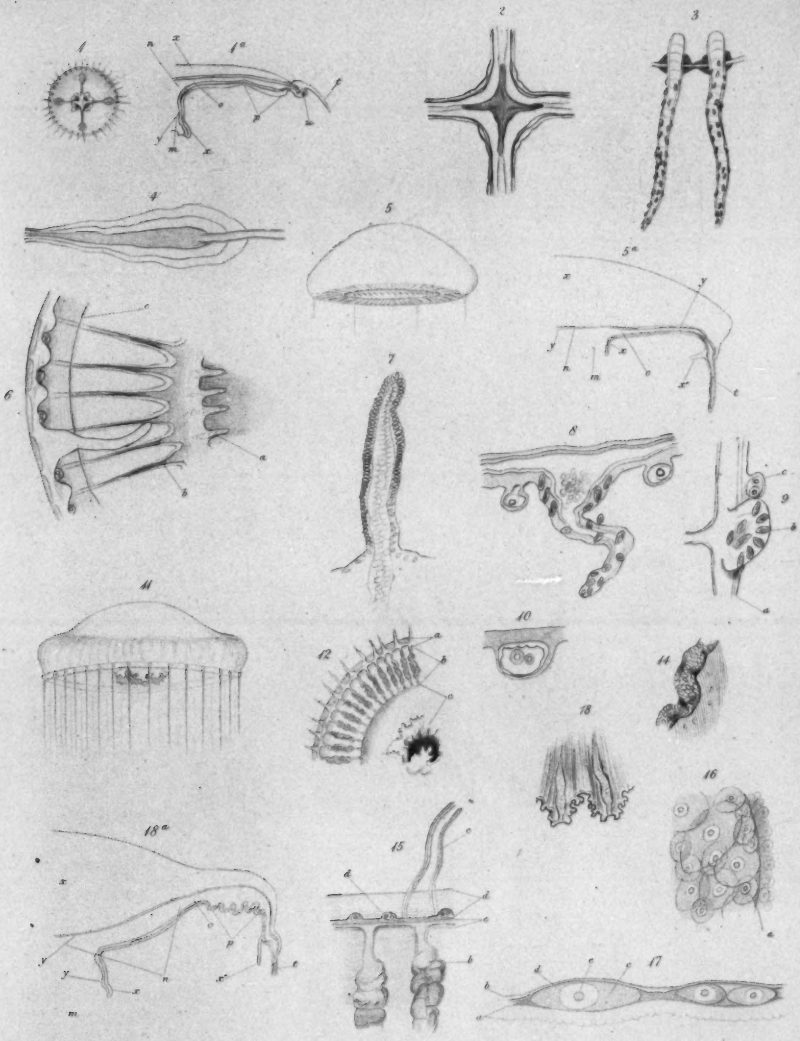
1
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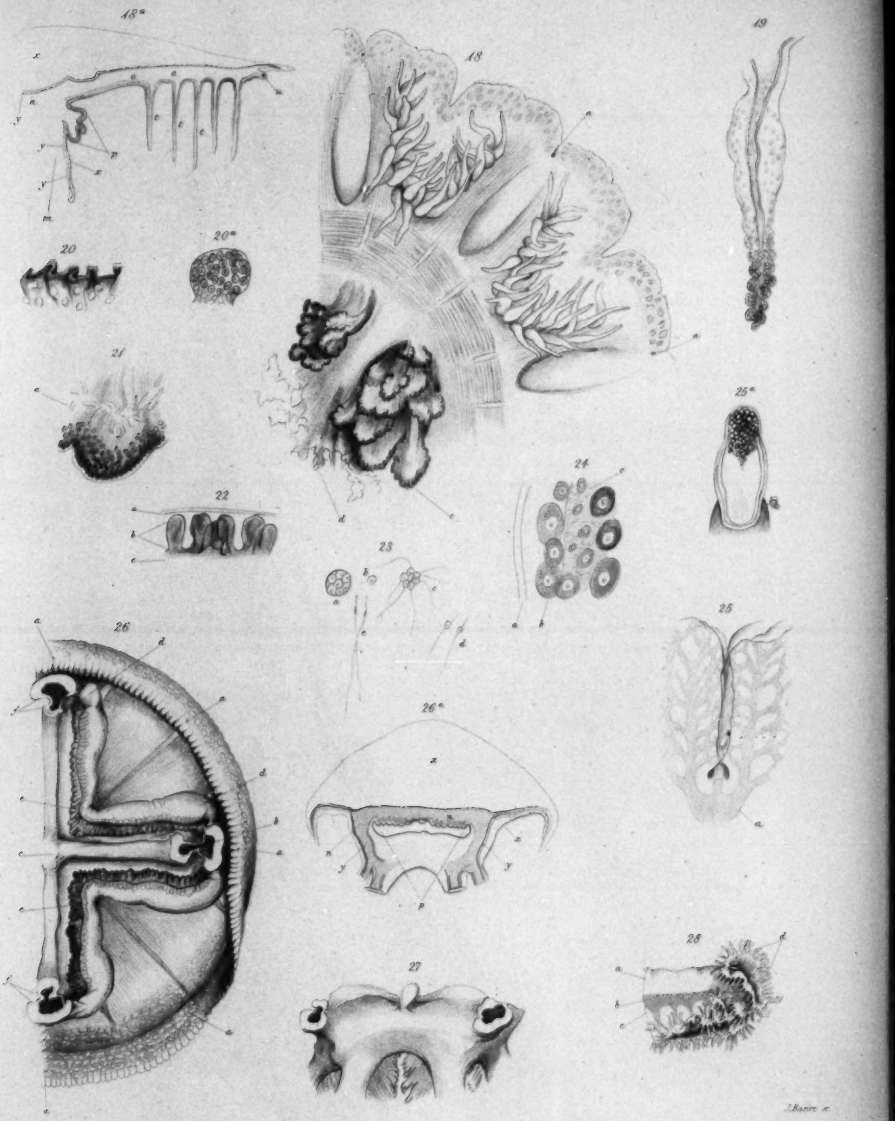
18a
18
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25a
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26a
27
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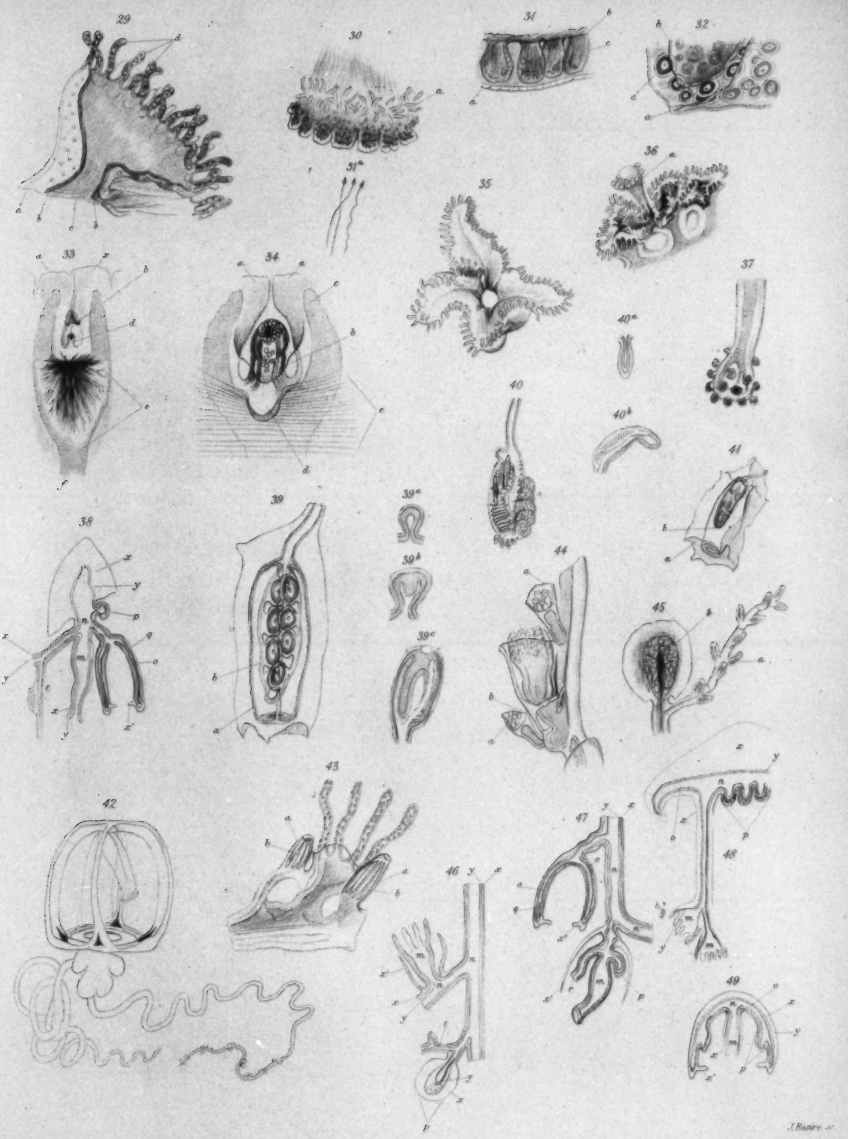
J. Basire sc.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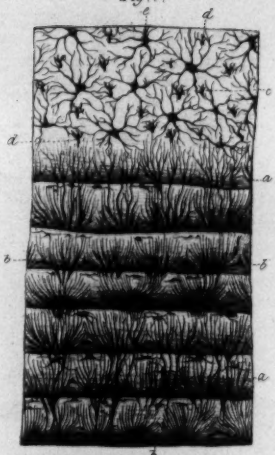
J. Basire sc.

Fig. 1.

Fig. 4.



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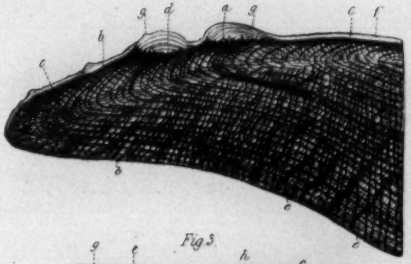

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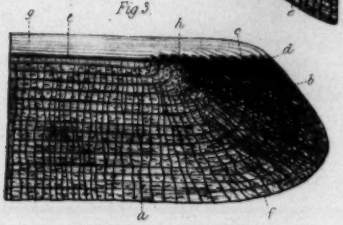

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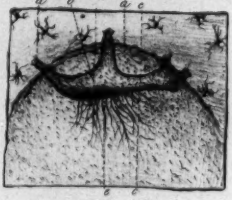

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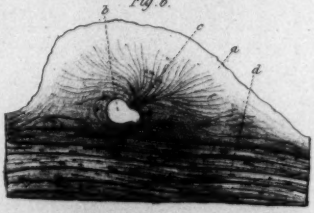

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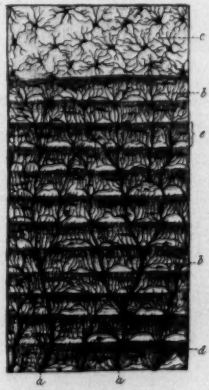

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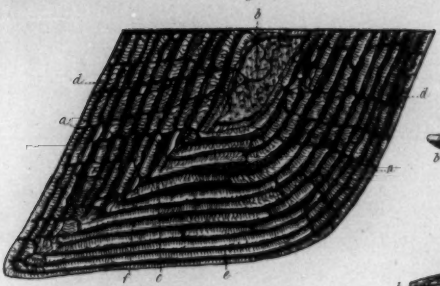


Fig. 9.

Fig. 9*.

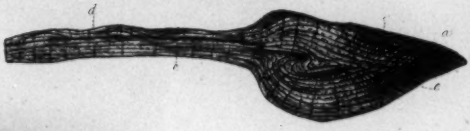


Fig. 10.

Fig. 11.

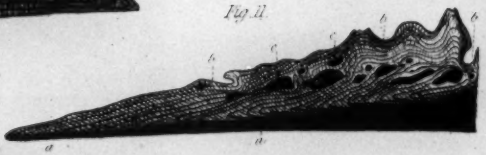
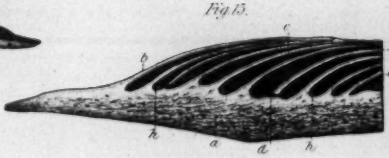


Fig. 12.

Fig. 13.



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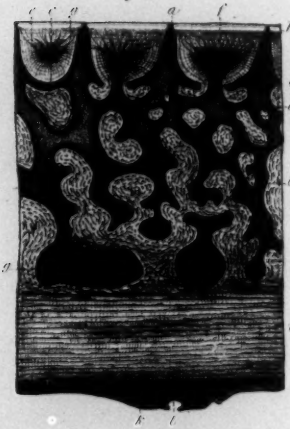

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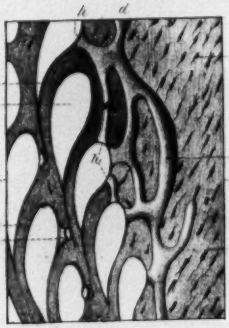

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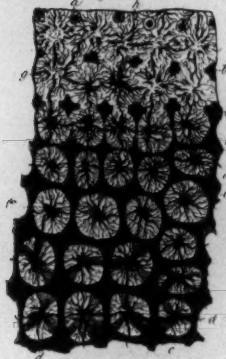


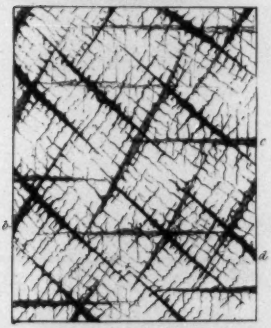
Fig. 17.

Fig. 21.

Fig. 18.

Fig. 22.

Fig. 19



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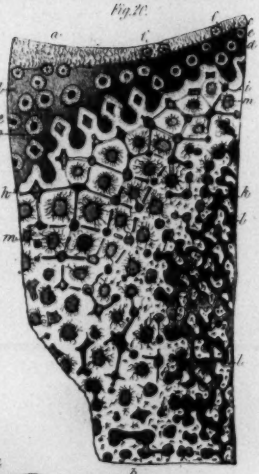

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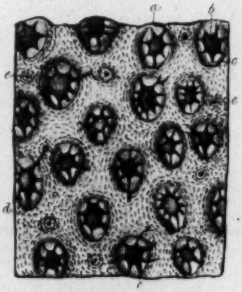


Fig. 23.

Fig. 26.

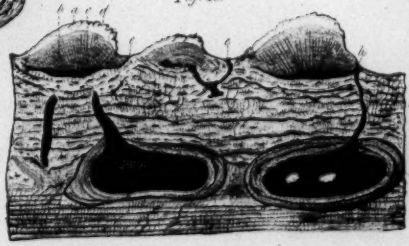
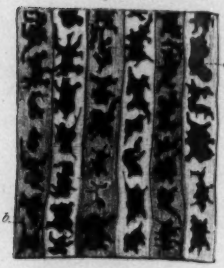


Fig. 24.

Fig. 27.

Fig. 28.

Fig. 29.



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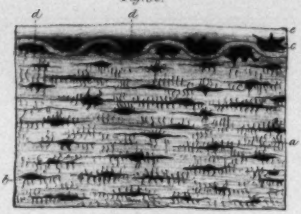

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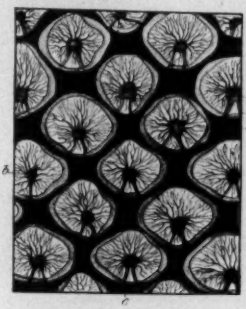

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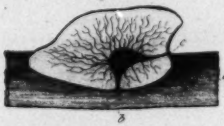

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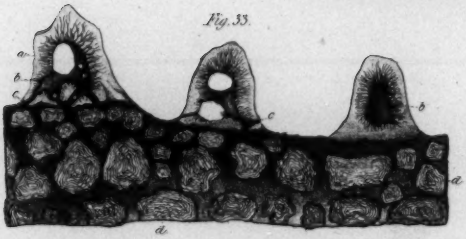

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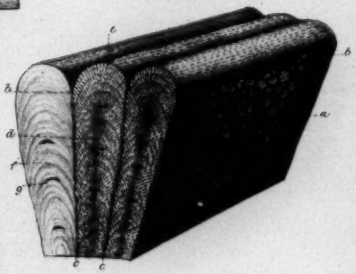

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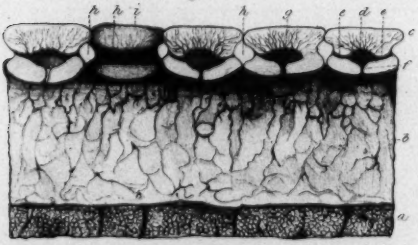

Fig. 35.

Fig. 37.